Homework corrections in upper-division physics courses: student and instructor motivations

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It is widely recognized that problem solving is a vital skill for physics students to learn. One element of expert-like problem solving is reflecting on one's solution and iterating as necessary. In upper-division physics courses, students are typically given ample opportunity to practice problem solving in the form of homework; however, there is often not much structure in place for reflection and iteration. One potential avenue for formalizing this revision process is homework corrections, in which students earn points back for submitting corrections to their homework. While potential benefits of homework corrections are apparent, instructors have also voiced concerns, and further research is necessary to understand if and how homework corrections can be implemented effectively. As part of a larger study analyzing the implementation of, and participation in, homework corrections, we present instructor motivations for offering homework corrections and student motivations for engaging with them.

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I. INTRODUCTION AND BACKGROUND

Problem solving is a vital skill for physics students to learn and has been studied extensively in PER (e.g., [1–3]). One important element of problem solving is reflecting on one's solution and iterating as necessary [4]; indeed, reflection is cited as a specific step in assessments of problem solving [5]. This element is particularly relevant when preparing students to engage in authentic problem solving as, in both academia and the workforce, problem solving is highly iterative.

Despite the importance of reflection and iteration in problem solving, they are often not emphasized in upper-division physics courses. These courses are usually structured such that the primary place students get practice problem solving is on homework assignments, and the problem-solving process typically ends when students turn in their assignments. Instructors may post solutions and hope that students compare their own answers to the solutions, but initial studies show that upper-division students do not automatically learn from their mistakes without external motivation [6].

One potential mechanism to motivate students to engage with this reflection and revision process is homework corrections (HWCs). Here, we broadly define HWCs as any opportunity for students to earn credit for correcting their homework assignments; however, there are a variety of logistical choices that can be made within this structure.

We hypothesize that the implementation of HWCs could both improve students' content understanding and have epistemological and affective benefits. By formalizing this revision process, instructors are not only motivating their students to reflect on the content of the solution and the problem-solving process but also sending a message about the nature of learning and the role of making mistakes. This messaging is part of creating a constructive error climate in the classroom, and initial work indicates that such a climate supports academic achievement [7]. When surveyed, instructors welcome errors as part of learning [8] and anecdotally, instructors often tell their students that "making mistakes is part of learning;" however, traditional course structures are often not aligned with this message. Integrating HWCs into a course demonstrates to students that making mistakes is an expected and valuable part of the problem-solving and learning process. Further, HWCs have the potential to reduce students' fear of making errors [8] and stress over losing points, which is both positive in and of itself and may reduce students' motivation to use unauthorized resources.

While HWCs offer apparent benefits, we do not know how students engage with them or how to best implement corrections to align with student and instructor goals. Research with younger physics students has shown that self-diagnosis activities can promote students' learning but that their ability to self-diagnose depends on the level of support provided [9–11]. Further work has looked at quiz corrections in upper-division physics courses, finding they are generally beneficial for student learning but there is still room to optimize implementation [12, 13]. These studies are complemented by research investigating students' epistemologies while reflecting on solutions, finding students' strategies vary as a function of physics background [14]. The existing work suggests the importance of providing scaffolding to support reflection and the necessity of being considerate with implementation.

This paper is part of a larger project studying the implementation of and engagement with HWCs. As an initial step in this work, we present instructor motivations for offering HWCs and student motivations for engaging with them. Identifying these motivations is a necessary step in determining how to effectively implement HWCs. Additionally, examining instructor motivations will help us situate this in the larger institutional change literature.

II. CONTEXT AND METHODS

This research was conducted at the University of Colorado Boulder in Spring 2023 and Fall 2023. In the Physics Department, a fraction of upper-division course instructors implement HWCs, but the exact number varies by semester. The data collection included an instructor survey, instructor interviews, student surveys, and student interviews.

Instructor Survey and Interviews: A survey was sent to all instructors in the department, specifying that responses were requested from both faculty who have and who have not implemented HWCs. Instructors were asked if they have ever implemented HWCs and what motivated this decision. They were then asked if they would be willing to elaborate on their thoughts in an interview. Twenty instructors responded to the survey, and nine of those participated in interviews.

Homework Correction Logistics: All of the students included in this study were enrolled in junior/senior-level Quantum 2 and had previously taken Quantum 1 with the same instructor. HWCs were implemented the same way in both of these courses. Homework assignments were due on Thursday nights, and full solutions were posted on Friday morning. If they chose to do HWCs, students had until Saturday at noon to do so by annotating their submitted homework. The students had to include a reflective statement about what they did wrong and what the correct approach should have been. The students are given the following example of a correction that would receive full credit:

> *"I did not notice that we were differentiating with respect to a parameter INSIDE the integral, I thought we were differentiating with respect to a LIMIT of integration. So I incorrectly invoked the fundamental theorem of calculus, when instead I should just have used a partial derivative. Fixing that changes my answer to <blah>... Next time, I need to watch out for which variable is being integrated over."*

HWCs could only be done on questions that the student had attempted in the initial submission. Graders then graded the annotated version of the homework and were instructed to award full points if the student correctly assessed what they did wrong and what the correct approach should have been.

Student Surveys: Throughout the semester, students were surveyed four times as part of the standard course content (i.e., no worry of survey fatigue), three of which are relevant to this analysis: the first week of the semester (S1), after their second homework (S2), after their first exam (S3). In S1, students were asked about their experience with HWCs in Quantum 1, including how often they had completed HWCs and what motivated their decision as to whether or not they would complete them each week. Their responses were then coded to identify the most frequent reasons students gave for completing or not completing their HWCs. On S2, they were asked if they did any HWCs on the most recent assignment and what motivated this decision, with the "select-all" options based on the coded responses from S1. S3 was given after their first exam and asked the same questions as S2, with one additional option addressing the recent exam.

Student Interviews: Interviews were conducted in Week 11 of the semester. In these interviews, students did their HWCs for the week in a "think-aloud" style and were then asked more general questions about their experience with HWCs. Nine students participated in these interviews, and two students interviewed together, at their request. Demographic information was not collected from the students. However, we note that the demographics likely track those of the institution, which is an R1 with a predominantly white population.

III. RESULTS

A. Instructor Motivations and Goals

Of the 20 instructors who responded to the survey, 11 said they had offered HWCs before. Nine of the twenty participated in interviews, and seven of those had offered HWCs in courses including Modern Physics, Quantum, Classical Mechanics, Statistical Mechanics, and Electricity and Magnetism. Several of those interviewed could not remember the exact details of how they had implemented HWCs or said that implementation had not been consistent from semester to semester, so we cannot detail each instructor's method of implementation; however, most described a method similar to that discussed in section II. Variations included some instructors requiring a full rework of the problem and one instructor only giving partial credit for corrected problems. Only one instructor described a significantly different implementation. In their courses, students would complete HWCs for one assignment on the next week's assignment. The students were then awarded bonus points for their corrections, which effectively gave them points back on the initial assignment.

First, we will present instructors' motivations for implementing HWCs, and then we will discuss their concerns. One main motivator for many instructors was wanting to incentivize students to look at the provided homework solutions and reflect on their own answers. One instructor states, "My hope was that by going through the solutions carefully, and kind of self-assessing the first round, that they will actually learn the things they did wrong in the homework." Another instructor specifically mentioned wanting their students to look at the solutions immediately after doing the work, rather than after the homework has been graded or just before exams. Some instructors discussed a more metacognitive component of this, with one saying that they "want students to learn from their mistakes and reflect on the learning process."

A few instructors discussed the nature of homework, stating that they are motivated to make homework "an iterative process" and "considered developmental (formative) vs. evaluative (summative)." One instructor noted that learning from one's mistakes is a "critical professional behavior" and that correcting and learning from mistakes is "something that physicists do." Others' stated motivations were more related to students' affects, with instructors discussing "a reduced fear of making mistakes," "boosted morale," and "reduced grade stress." More broadly, several instructors stated that they had implemented HWCs to reduce stress and make it easier for students to succeed; a few of them specifically mentioned the COVID-19 pandemic in relation to this motivation. One instructor explicitly mentioned that "decreasing the emphasis on 'getting it right the first time' reduces the use of canned answers or answers copied from colleagues or from online sources." Another instructor similarly hypothesized that HWCs "perhaps reduce some motivation for inappropriately using web solutions sources."

Next, we present instructors' concerns regarding implementing HWCs. Logistical issues were a concern for many instructors but were particularly dominant for instructors of large, introductory courses. One instructor specifically said, "It literally is, it's logistics, it's time. It's time multiplied by, you know, 500 students." Separately, they specified being concerned about the time required to grade: "It's just down to TA time...it would probably push them over what they're supposed to do." TA involvement was mentioned as a concern by several instructors, including those teaching comparatively smaller upper-division courses. One instructor who had implemented HWCs spoke of making sure that graders were not overloaded with work, specifying "The TA loads here are very heavy...if you had them grade it twice, that's an enormous amount of work." Some instructors were specifically worried about the potentially more nuanced grading that HWCs would require. One instructor responded to the survey saying, "My feeling is that the corrections are only meaningful if I can have someone check that they have meaningfully explained the changes. I lack the manpower to do that at the moment." Another instructor explained that "[doing reworks] makes [grading] hard, it's like another layer of labor and a different kind of evaluation. You're less paying attention to right or wrong, which is easier for grad students."

This need for more attentive grading to make sure students are accurately assessing their errors and not just copying down the solutions hints at the broader concern that the implementation of HWCs may mean that students may put less effort into the initial assignment. One instructor described that "some of the students realize that they can just submit

some kind of not very well worked out homework solution, and then still get 100% credit for the rework," specifically mentioning one student who said, "I'm not going to spend much time on the first round because I know I cannot do it anyway." Despite this concern, the instructor goes on to comment that they recognize students can also just copy homework answers from their peers, so "this cannot be turned off completely." Some instructors similarly recognized the potential for students to "game the system" but were not too concerned with this. One instructor argued that there is a potential benefit to a version of this behavior, saying, "It's not clear to me that beating your head against a wall for too long is helpful in terms of learning" and that there is a case to be made for the student who plans for doing HWCs and decides, "That's when I'm going to do the second half of the learning."

Some instructors also indicated concern around inflating homework grades. One instructor responded to the survey saying he had not implemented HWCs, in part because "it arguably makes the homework portion of a student's grade less meaningful." Only one instructor who had implemented HWCs actually indicated concern about homework grades, saying they wanted to give only half of the points back for corrected problems but did not do that because it would be extra work for TAs. This instructor then explained, "What I'm starting to do is actually lowering the overall percentage the homework score is for the full, the course score." Many instructors, however, indicated that this was not at all a concern for them. Some focused on the intent of homeworks, saying they primarily viewed homework as a place for students to learn. Others stated that this was not a concern for them because the majority of the course grade still comes from exams, not homework.

B. Student Motivations and Goals

1. Student Surveys

In S1, students were asked about their experience with HWCs in the previous semester. The students' responses from S1 regarding their motivation to do or not do HWCs each week were coded to get the following options for S2/S3:

What motivated your decision to complete homework corrections (or not)? Select all that apply

- ☐ *I wanted to improve my grade*
- ☐ *I wanted to better understand the content*
- ☐ *I wanted to learn from my mistakes*
- ☐ *I didn't have enough time*
- ☐ *I thought I would be happy with my original grade*
- ☐ *I already understood the content well enough*
- ☐ *I had intended to but forgot*
- ☐ ***(Only on S3)** My confidence about the first exam*
- ☐ *Other (feel free to elaborate in the final text box)*

On S2 and S3, 22 (out of 47) and 18 (out of 40) students said they had done HWCs on the prior week's homework assignment. The responses to the question asking about their motivation can be found in Fig. 1 and Fig. 2, which are split by whether or not the student did HWCs. The response "My confidence going into or performance on the first exam" is on both plots because this was selected by students in both motivation categories. One response from each survey is not included in the results due to contradictory selections.

Student	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Times doing HWCs	1	4	11	11	3	6	10	2	4
HW Average	80	97	100	100	88	99	100	96	97
Final Grade	C	B	B-	A	B	B	A	A	B

TABLE I. Information about interviewees. There were 11 HW assignments and the HW average was calculated including the benefit from HWCs and with their lowest grade dropped.

2. Student Interviews

In the interviews, students were asked what motivated them to do or not do HWCs each week. The factors students discussed can be summarized as falling under *Content Understanding*, *Grade*, and *Time*. We will present some examples of how specific students discussed weighing these factors. To provide context, Table I provides information about the interviewees' grades and participation in HWCs.

Four students discussed an improved understanding of the content or an opportunity to learn from their mistakes as a motivator. Student 3 said, "It helps me understand where the [expletive] I went wrong." Student 7 cited challenging material, saying "I was just kind of hovering between I think I get it, and I don't think I get it, and homework corrections were kind of helpful on that." Student 4 tied a better understanding of the content to their grade: "I want to know what I got wrong so that I don't get it wrong on the exam."

Four of the students discussed grades as a motivator. Student 5 said, "I would look at the week, and I would go 'how many questions was I not confident on on that homework?' And so it was more of a points thing for me." While the grade

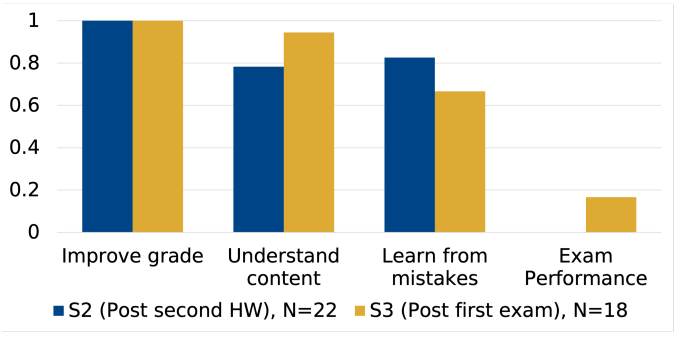

FIG. 1. Students' motivations for completing HWCs for two weeks. The question was "select-all" in format, and each bar represents the percentage of those who did HWCs who selected that option.

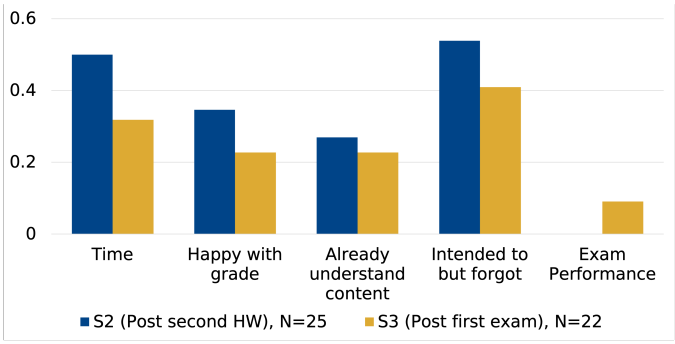

FIG. 2. Students' motivations for *not* completing HWCs. The question was "select-all" in format, and each bar represents the percentage of those who did not do HWCs who selected that option.

benefit was enough of a motivator for some, others found themselves balancing the grade benefit with the time required to complete HWCs. Student 9, for example, says, "It usually ends up being time...so if I'm like busy with other things, in my mind, it's a, you know, lose maybe five or so percent on the homework. So I can go finish other more pressing matters." Similarly, Student 8 discussed generally being content with their homework scores, saying, "I'm happy with getting like a 90 or like a 95 or 85 or something. So, I see their value, but it's just like, the timing is not good for me."

There were also a couple responses representing more unique perspectives. While discussing how HWCs were beneficial from a grade perspective, Student 3 said, "It's good knowing that I can do homework corrections in the end, just so I'm not chasing like a perfect score on a homework assignment." While this comment is related to grades, it addresses a decreased pressure while initially completing the assignment, rather than a motivation that arises afterwards. Student 7 said, "A lot of times it was just like...I know I bombed this assignment. I don't have the wherewithal to go look at all the mistakes I made today...I've been a lot better about doing that lately, especially because like 100% point forgiveness is huge." The student indicates not wanting to look at their homework because they know they did poorly but also notes that they are motivated by the grade benefit.

IV. DISCUSSION AND FUTURE WORK

We have presented the motivations and concerns of instructors with regard to implementing HWCs, as well as student motivations for engaging with them. Most instructors discussed wanting students to look at the posted solutions and reflect on their own work. Some specified more metacognitive and epistemological goals, wanting students to learn from their mistakes and understand the iterative nature of problem solving. Additional motivations were related to students' affect, with instructors stating they wanted to decrease students' stress and fear of making mistakes. While almost all instructors noted some potential benefits of implementing HWCs, they had a number of concerns as well. Many of the concerns were logistical in nature, with instructors worried about the additional grading workload and more nuanced grading that HWCs would require. The logistical concerns were especially relevant for instructors of larger courses. Some instructors indicated being worried about students putting less work into their initial assignment. Others were either not worried about this or recognized that there will always be ways for students to behave in similar manners. Some instructors expressed concern about inflating homework grades; however, this was a minority opinion. When considering instructor perspectives, it is important to note that all the instructors teach in a physics department with a culture accepting of course reform and may be more open to instructional change than the average physics faculty member. However, this also means that their concerns are likely common within the field.

We see that students are clearly motivated by grades, with every student who completed HWCs indicating that the grade benefit was part of their motivation. Many students also noted that they were motivated by improving their understanding of the content and learning from their mistakes; this indicates that students at least see HWCs as beneficial from more than a grade perspective (keeping in mind these motivations are self-reported and may be post-rationalized). While grades were clearly a motivator, we also note that even giving students the opportunity to get full points back was not enough of an incentive for many of them, and students are balancing content understanding, grades, and time. We expect, therefore, that students' engagement may change based on other elements of the course. We also saw some students comment on the stress they experience around homework grades and making mistakes, and it appears possible that HWCs have helped some students with this.

We see notable alignment in instructor motivations and student behavior, suggesting that HWCs could help with content understanding, emphasize the iterative nature of problem solving, and reduce student stress. Additionally, it is understandable that some instructors are concerned about students "gaming the system," but initial perspectives from students make us optimistic that this may not be a significant issue.

For future work on this project, we plan to conduct a larger study looking at implementation of and engagement with HWCs in many courses with different instructors; this will include analysis of the HWCs themselves, as well as a more quantitative analysis of student performance. The results of this paper will inform our future work and provide essential context when developing a framework to help instructors implement HWCs in a way that aligns with their goals.

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