Quiz Corrections: Improving Learning by Encouraging Students to Reflect on Their Mistakes

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Most introductory physics instructors administer several quizzes and/or exams each term. Instructors are willing to invest the significant time it takes to develop, administer, and grade these assessments because they believe that regular assessments help students learn. However, instructors also believe that students do not make full use of the learning potential of these assessments. For example, in an interview study, six college physics instructors were asked how they expect their students to utilize an instructor solution after a test. All said they expect students to compare the instructor solution with their own and learn from any mistakes made. However, the instructors all thought that most students do not do this sort of comparison and only look at solutions superficially, if at all.[1]

A study of college students confirms this perception. In an anonymous survey, 456 first-year engineering students were asked to describe what they did with their graded exams.[2] The majority responded that they looked at the grade and then filed it away. Only 21% said that they would use the exam again later. Of this 21%, many indicated that this would only be if the final exam were cumulative.

One of the interviewed instructors suggested that in order to change this undesirable student learning behavior, students could be asked to turn in a corrected test.[1] He quickly dismissed this idea as being too labor-intensive. We, however, have experimented with methods for dealing with this sort of assessment correction that require minimal instructor time. In this paper we first describe several variations of the use of assessment corrections. We then provide some theoretical arguments supporting this practice. Finally, we provide some data related to its effectiveness. Although we will occasionally use terms such as "quiz corrections" or "exam corrections" to refer to the correction of particular types of assessments, we will typically refer to these practices generically as "assessment corrections."

The Use of Assessment Corrections

We have developed several variations of assessment corrections through informal experimentation in our own introductory physics courses during the last few years.[3] Bob Brown at Case Western Reserve University has pioneered many innovations in introductory physics teaching. One of them, which he started when KH was his teaching assistant, was exam corrections. Over the years, he has modified the assignment and reported on its effectiveness.[2] In Bob's current model, students receive a copy of the exam solutions with their graded exams and are given the assignment shown in Fig. 1.

KH has used a modified version of this assignment in her introductory calculus-based physics courses at The Ohio State University and her nonmajors astronomy course at Denison University. Students are given two days to correct any errors they made on the exam; solutions are not posted until after the corrections are due. Submitting the corrections is a required assignment for those who score less than 90% on the exam and it is weighted the same as any other homework

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When you get your exam back, please go through it and briefly correct all of your mistakes: squeeze the corrections right onto the exam answer sheets themselves – use a *different colored pencil or pen so we can identify your new remarks.* Also, explain in only a few words (again, squeeze them right onto the exam answer sheets) why you made the mistakes you did (e.g., you misread the problem, you made an algebra error, you thought something was conserved that wasn't, etc.) Please don't just say "you didn't have a clue"; you very likely can tell us more than that about what stopped you from proceeding further. Hand back the corrected and explained exam with your other homework and we'll get it back to you when we give you back that homework after grading. You – and we – will learn from this!

Fig. 1. Exam correction assignment used by Bob Brown in his introductory physics course.

Syllabus description

Midterm corrections: To assist you in using your graded midterm exams as learning tools, we require that you turn in corrections to any problems you missed. These will be due at the recitation after the exams are handed back. While writing these corrections, you may consult with any resources, including the book, classmates, or instructors. You will receive all 10 points for an honest effort. If your score on the midterm is 90% or greater, you do not need to submit the corrections and will receive 10/10 for the assignment.

Email

Today you received your exams back in recitation. As you've seen in the syllabus and heard from us in class, you are to look over the exam and turn in corrections to anything you missed. You can consult any resources, including the book, other students, the Internet, and anyone on the instructional staff. We want you to understand what you did wrong so that you will not make the same mistakes again later! Please write your corrections on separate paper, and include a short statement about why what you did originally was wrong. Submit the corrections, along with your original exam, at the beginning of recitation on Thursday.

Fig. 2. Syllabus description of exam correction assignment and follow-up email used by KH in her introductory calculus-based physics courses.

assignment. Grading is basic—students receive full credit for an honest attempt, zero for not submitting it, and half credit for a partial attempt. Figure 2 shows a statement on the syllabus describing the assignment, plus an email she sends to the students.

CH developed a similar quiz corrections assignment for his introductory calculus-based physics course (see Fig. 3.) In this class, weekly quizzes contribute 15% toward students' final grade. Although there are other exams, corrections are only used on the quizzes, which CH views as formative assessment. Similar to KH, students have two days to complete the assignment. Since the assignment is graded as "all or nothing," grading is relatively quick. For any given quiz, it is typical for 50-75% of the approximately 75 students in the course to submit a quiz correction. As it is not necessary to read every word, grading and recording the scores for each set of quiz corrections typically takes about one hour. Late in the semester, once students have been well trained, the process can be even quicker.

Although the idea behind these corrections is quite simple, as with most things, the difference between strong success and marginal success is in the details. We consistently find that, although most students are capable of performing the diagnosis phase of the corrections (i.e., what did I do wrong?) they typically have trouble with the generalization phase (i.e., how do the specific difficulties I encountered relate to the general principles or procedures of physics?). Students need to be constantly reminded of the need to generalize beyond the specific problem. To help scaffold students in this generalization, CH has developed a more detailed description of what is expected from students.[4] In addition, after students turn in the first quiz correction assignment, CH typically returns about half of the submissions without credit because of this lack of generalization. On the first assignment only, students are permitted to make a second submission to correct this deficiency.

The Theoretical Basis for Assessment Corrections

In this section we briefly describe how the use of assessment corrections is consistent with current research-based understanding of how students learn.

Formative Assessment: *Feedback (and student processing of feedback) is the most important part of learning.*

One issue that is apparent in the responses to the student survey we mentioned earlier is that the students view assessments as summative.[2] We (along with many instructors) would like students to utilize the formative potential of assessments. The value of formative assessment has been documented by Black and Wiliam, who conducted an extensive review of the formative assessment literature.[5] They concluded that the effect of the use of formative assessment practices on student learning is larger than for most other educational innovations. The idea is simple. Students must be aware of specific gaps between their existing understanding and the desired understanding before they can attempt to fill these gaps. Unfortunately, the research concludes that the grading (summative) functions of assessments are often overemphasized while the learning (formative) functions are underemphasized.[5] Thus, although many teachers may view quizzes and intra-term exams as an opportunity for formative assessment, it is usually left up to the students to take advantage of that opportunity. Since the students often view these assessments as summative, they fail to reflect carefully and learn from their performance.

Metacognition: *An ability to think about one's own thinking and monitor one's current level of understanding is essential for learning.*

Metacognition is the ability of a learner to monitor his or her current level of understanding and decide when it is not adequate.[6] Redish identifies "metalearning" explicitly as an important learning goal: "Our students should develop a good understanding of what it means to learn science and what they need to do to learn it. In particular, they need to learn to evaluate and structure their knowledge."[7] Like anything, these metalearning skills can be improved through practice, guidance, and encouragement. Ideally, we would like our students to be able to use their metalearning skills to identify any knowledge gaps that exist and then determine what questions must be asked or resources consulted to fill them. Assessment correction assignments can help students develop these skills by confronting them directly with the gaps in their knowledge identified by the graded assessment, with the expectation that the student will explicate the nature of each gap and determine how to fill it.

Personal Epistemology: *Student beliefs about knowledge and learning have a significant effect on their approaches to learning and their learning outcomes.*

Research suggests that many student beliefs about knowledge and learning are counterproductive for learning.[8] As with other types of beliefs, these counterproductive beliefs can be refined and modified via appropriate reflection.

Quiz Correction Cover Sheet

Name: ______________________
Quiz #: ______
Group #: ______

Quizzes are designed to be a learning experience. Therefore, you can improve your quiz score by carefully reflecting on your performance and learning from it. Completing this assignment appropriately will allow you to increase your quiz score by half of the points that you missed. This is an all-or-nothing assignment. It is intended only for those students who are interested in making a serious effort to improve their understanding. If it is not done well, you will not receive any additional points.

To receive credit for your corrections, you need to address the following **two phases** for **each** question or problem that you did not receive full credit on. See detailed description of each in the separate document.

1) Diagnosis Phase (DP) – Identify what went wrong.
2) Generalization Phase (GP) – Learn from your mistakes by generalizing beyond the specific problem.

Please **type** your answers below and use additional pages as necessary. Be sure to attach your quiz paper so I know what you are talking about.

Fig. 3. Quiz correction assignment used by CH in his introductory calculus-based physics courses.

Students often believe that learning science means receiving facts from an expert rather than constructing their own understanding.[9] If they perform poorly, they may believe that they had just not received enough or the correct type of knowledge. Reflecting on their performance can allow students to understand that they had not assimilated the knowledge enough to apply it to a new situation. Additionally, making corrections forces the students to play an explicit and active role in constructing understanding.

Similarly, students are often unaware that if they don't understand something right away that they can take steps to help them make sense of the topic.[9] Thus, if they do poorly on an assessment, students may assume that it must be because the material is too difficult for them to understand. By reflecting on their performance, students may begin to understand previously misunderstood topics and to see the process by which such understanding can be developed. Through repeated experience with assessment corrections, students can begin to develop metalearning skills to enable them to diagnose and remedy deficiencies in understanding on their own before (rather than after) quizzes and exams.

Understanding Students: *Effective teachers understand where their students are, what they are thinking, and how they are interpreting information provided in the course.*

Redish's fourth "teaching commandment" says we should find out as much as we can about what our students are thinking.[7] In fact, many of the founders of the current Physics Education Research movement began to work on instructional improvements after investigating student thinking and realizing that students were getting very different things out of the course than had been intended. Without an understanding of what his or her students are thinking, an instructor is not able to design appropriate instruction. We are constantly surprised about how students have misunderstood a concept or how they have misinterpreted a question (sometimes the result of poor student understanding, sometimes the result of a poorly written question). Thus, assessment corrections not only help students improve their learning, but also help instructors improve their teaching.

The Effectiveness of Assessment Corrections

Although we have not conducted rigorous experiments to evaluate the effectiveness of assessment corrections (i.e., no control groups were used), we consistently find that: A) Students have large gains in conceptual understanding in classes where assessment corrections are used; B) Students believe that assessment corrections help them learn; and C) Assessment corrections appear to lead to more meaningful learning for many students.

• *Students do well on nationally normed conceptual evaluations in classes where assessment corrections are used.*

Table I shows data from several of our courses on the Conceptual Survey of Electricity and Magnetism (CSEM), a 32-item multiple-choice survey of student understanding of topics covered in a typical introductory electricity and magnetism course.[10] Results are presented in terms of the average normalized (or Hake) gain[11] [<*g*>=(post% – pre%)/(100 – pre%)]. The results from our courses compare favorably to both traditional and innovative[11] physics courses at other universities. Without the use of a controlled experiment, of course, it is impossible to say what portion of these gains is due to the use of assessment corrections and what portions are due to other aspects of these courses.

• *Students believe that assessment corrections help them learn.*

Classroom surveys and informal conversations with students in our courses suggest that students believe the correction assignments help them learn.

In CH's F04 WMU electricity and magnetism course, students were asked to rate 13 class components in terms of how helpful they were in helping them "learn physics." Quiz corrections received the highest ratings, with 50% of the students rating it as extremely helpful for their learning of physics and another 25% rating it as somewhat helpful. One might think that students rated quiz corrections highly because they perceive these as helping their grade. However, the second- and third-highest ratings went to class lectures and the textbook. Neither of these course activities directly affected student grades. This suggests that students were indeed responding in terms of activities that they perceived as helping them learn physics. The results of a similar survey in F06 were comparable.

Table I. CSEM scores for pilot quiz correction courses (students who took both pre- and post-CSEM).

	W04 (OSU)	F04 (WMU)	W05 (OSU)	F06 (WMU)	Comparison University Data ("traditional" courses)
	N = 194	*N* = 46	*N* = 210	*N* = 107	
CSEM Pre	33.8 ± 1.0%	32.0 ± 1.5%	33.2 ± 1.2%	28.2 ± 1.0%	31 ± 0.3% (national sample[10])
CSEM Post	71.0 ± 1.1%	64.2 ± 2.1%	70.2 ± 1.1%	61.7 ± 1.4%	47 ± 0.5% (national sample[10])
<*g*>	<*g*> = 0.56	<*g*> = 0.47	<*g*> = 0.55	<*g*> = 0.47	<*g*> = 0.23 (national sample[10]) <*g*> = 0.15 (NCSU[13])

In KH's W05 OSU electricity and magnetism course, a similar survey asked students to rate seven aspects of the course according to their usefulness in learning the material. Exam corrections received an average rating of 4.2 on a 5-point scale, with 5 indicating extremely helpful.

• *Assessment corrections appear to lead to more meaningful learning for many students.*

Based on what students write on their corrections and informal interactions with students, we believe that the correction assignment leads to more meaningful learning for many students. For example, since using quiz corrections CH has noticed that many more students come to ask about particular questions (not to argue about their score, but to understand the physics!) than in the past. KH's teaching assistants for her S05 electricity and magnetism course spontaneously reported that they believe the students take the exam corrections more seriously than they do the standard homework assignments. Additionally, she typically has as many or more students visit her office during the time they are working on the exam corrections as in the days immediately preceding the midterms.

We also find that implementing assessment corrections has led to more effective use of class time and more pleasant interactions with students when assessments are returned. Many instructors are surely familiar with the phenomenon of handing a graded exam back and then asking if there are any questions about it. This often leads to wasted class time for students who did well on the exam, as well as for students who would learn the material better by reviewing the assessment in a more relaxed mode later. Further, many instructors have doubtlessly experienced the "mob" mentality that can take over a class when an exam on which they performed poorly is returned. We find that these types of incidents are almost completely eliminated when assessment corrections are implemented, making the testing experience less stressful for both the students *and* instructors! Finally, it does happen (perhaps more than it should) that when we read over the students' work, we find that part of the difficulty students encountered was because we wrote an ambiguous question; we learn from the experience, too.

Summary

We have found assessment corrections to be a valuable aspect of our teaching. The use of assessment corrections is consistent with the literature on student learning and appears to contribute to strong student learning and an improved class atmosphere in our classes. This instructional tool has the potential to not only improve student learning of physics content, but also to improve self-monitoring and reflection skills. Further, we have found that incorporating quiz corrections saves instructional time, since almost no class time is needed to review returned assessments, and the time that students spend in office hours is more efficient. We hope that this article will encourage other teachers to experiment with assessment corrections in their own classes.

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Detailed Description of Quiz Correction Assignment

1) Diagnosis Phase (DP) – Identify what went wrong.

In this phase you need to correctly identify your errors, and diagnose the nature of your difficulties as they relate to specific physics principles or concepts, a problem solving procedure, or beliefs about the nature of science and learning science.

Please note that an incorrect diagnosis or a merely descriptive work (such as simply noting the places where you made mistakes) is unacceptable. You need to analyze your thinking behind your mistakes, and explain the nature of these difficulties. Hence, in this phase you need to identify why you answered the way you did, where your understanding might have been weak, what you found difficult, what knowledge or skills you were missing that prevented you from correctly completing the solution, etc.

Poor Diagnosis	*Good Diagnosis*
No description of thinking behind difficulty • "I was confused." • "I thought it would be 5 N." • "I picked the wrong equation." • "I didn't remember to use F=ma."	Focuses on reasons for actions • "I thought that the larger velocity would mean the larger force." • "I knew it was angular momentum, but I didn't apply it correctly – I neglected the angular momentum of the ball about the pivot point of the rod."

2) Generalization Phase (GP) – Learn from your mistakes by generalizing beyond the specific problem.

In this phase you need to identify what deeper physics understanding you have gained from your diagnosis. By carefully thinking about the particular aspects that were problematic to you in approaching the question/problem, and correlating them with the correct solution, you should develop a better understanding of the basic physics principles. In your writing you should identify this new understanding and describe how it will prevent you from having similar problems in the future. Please note that merely stating the correct solution, by copying or paraphrasing the instructor's solution for a question is unacceptable. You are expected to generalize beyond the specific problem to discuss the general principles of physics.

In your writing you are very welcome to identify not only your understanding of your mistakes, but also your appreciation for the aspects of your thinking that were already correct and successful in your original attempt. It is hoped that you will hold on to the good elements you already have and add new good ones by doing these corrections.

Poor Generalization	*Good Generalization*
Focuses on generic activity • "I learned to read the question carefully." • "I learned to pick the right equations before solving a problem."	Generalizes beyond the specific problem • "I learned that the acceleration does not depend on the velocity. This is consistent with Newton's second law, which says that the acceleration depends only on the net force and the total mass."
Focuses only on the specific problem • "I learned that the amount of work from A to B is the same as the amount of work from B to C."	

Detailed description of quiz corrections distributed to students by CH.