After the Test: What Now? Post Assessment Reflection

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When an instructor returns a graded assessment, usually an exam or test, students typically throw it away, either literally or figuratively. Several studies have shown that successful students use their assessment results to self-reflect leading to self-correction, and further to more positive accomplishments and growth. Therefore, it would seem that requiring all students to self-reflect on their assessment results should promote increased academic success, and also give students the means to succeed beyond a specific class or assessment. Self-reflection after each assessment is especially necessary in mathematics since the topics in mathematics build one upon the other. If students do not understand one topic, they may not understand subsequent topics, leading to failure and frustration.

This article discusses my experience with post assessment self-reflection in teaching developmental, college, and calculus courses over the past five years. Realizing that exhortation to reflect without the tools to do so would be unlikely to bring results, I created a simple worksheet to be given to students at the same time that they received back their graded assessments. This approach shares some features with previous studies of student self-assessment, in that it focuses on increasing the responsibility of students in the learning process. However, it differs from them in its specific application to college level mathematics teaching, the length of experience in using the approach, broadening of the concept of self-reflection to include four-fold purposes, and its practical process to assist students to improve their performance in the course and beyond.

The article begins with a brief discussion of self-reflection as it applies to college mathematics students, and describes the context in which I created the self-reflection worksheet. The remainder of the article explains the worksheet, and discusses student responses and further strategies to encourage self-reflection. The concluding section summarizes insights gained through using the worksheet, and their implications for more effective teaching of mathematics to university students.

Self-reflection in studying mathematics

Self-reflection, in this context, involves students in a process of questioning and evaluating their performance in graded assessments, and working out and executing plans for future improvement. It is related to other terms, including self-regulation, self-assessment and self-monitoring, but differs from them in several important ways. *Self-regulated learning* has been defined as "an active, constructive process" during which students monitor, regulate and control their cognition, motivation, and behavior (Pintrich, 2000). It emphasizes students' setting goals (forethought), implementing and self-monitoring strategies to achieve them (performance), and developing new goals and designing new courses of action (self-reflection) (Zimmerman, 2011). *Self-monitoring* combines self-regulation with motivation, supplementing cognitive strategies (learn, remember, understand) with self-regulatory strategies (monitor, regulate, control cognition, motivation and behavior) so students gain ability to adjust their performance (Bercher, 2012). *Self-assessment* is "a process…during which students reflect on the quality of their work, judge the degree to which it reflects explicitly stated goals or criteria and revise accordingly." It is "a key element in formative assessment because it involves students in thinking about the quality of their own work, rather than relying on their teacher as the sole source of evaluative judgment." Similar to self-regulated learning and self-monitoring, it stresses setting goals, making plans to meet them, and monitoring progress (Andrade and Valtcheva, 2009).

All these approaches aim to encourage students to play a more active part in their own learning process, and to use their assessments to improve their performance. But until now, explicit references to self-reflection (though sometimes implicit) have been few. Where it is mentioned, it has generally been subordinated to the techniques discussed above, and limited in scope. For example, a study of anatomy and physiology students utilized a pre-test student assessment sheet, asking for students' percentage estimates of their mastery of listed objectives, and a post-test reflection sheet that asked how much the self-assessment percentages affected their test preparation time, and whether they did better, the same, or worse than they expected on the test (Bercher, 2012). A more elaborate approach aimed to enhance students' self-reflective responses to academic feedback through instructor modeling of error correction, guided self-reflection opportunities as part of a formative assessment process, and an incentive system that rewarded subsequent

attempts at learning. A self-reflection form asked students to make "task-specific self-efficacy judgments" before solving individual math problems, "self-evaluation judgments" after attempting each problem, compare these with their results, explain their ineffectual strategies, establish new effective strategies and indicate their confidence for solving another problem. They were also required to solve a similar problem, and specify the strategies and procedures in their work. The purpose of the design was to help students to self-reflect more effectively on their errors and to perceive academic feedback as opportunity for further learning (Zimmerman, 2011).

While my approach to self-reflection contains some of the same elements as those above, there are significant differences. First, few previous studies applied their techniques specifically to mathematics students, and of these the target populations were generally teachers and school students (e.g. Raymond 1995; Stallings and Tascione 1996), developmental students (e.g. Pope and Smith 2002), or students in developmental and introductory math classes (e.g. Zimmerman 2011). Second, although some studies involved quite large numbers of instructors and students, and collected statistical data from the responses in student worksheets that were compared with their subsequent performance, they were limited to a period of one or two quarters or semesters (some of these required a large amount of intensive work by instructors, which might not be sustainable for a longer period). Third, even where there was explicit use of the term self-reflection, as in Zimmerman's large scale study of technical college math students, the role of self-reflection was subordinated to concepts of self-efficacy and self-evaluation, and limited to questions on time and strategies for preparation, correction of problems, solving alternative problems, and estimates of confidence (Zimmerman 2011). In contrast, the approach I devised comprised a four-fold in-depth self-reflection worksheet, specifically designed for mathematics college students, and implemented across all the courses I taught over a period of several years.

Context

It is no secret that many students find college mathematics extremely difficult. Since mathematics courses are usually required pre-requisites for STEM (Science, Technology, Engineering, Mathematics) majors, they may constitute a stumbling block or even a deterrent to making career choices in these fields. A high dropout or failure rate in

mathematics courses is discouraging, particularly in the light of a broad recruitment effort to encourage under-represented groups to pursue STEM careers.

Why do some students find college mathematics so difficult? Possible explanations include poor school preparation, inappropriate approaches in pedagogy, and inadequate attention to variations in learning speeds and types. There have been a variety of responses – special teacher training, developmental education, more varied materials, on-line courses and supplements, math labs, promotion of small study groups. But these alone do not appear to have answered the problem of poor performance by some students that indicates inadequate mastering of material or lack of ability to apply concepts readily and fluently to problems.

My college serves a wide variety of students, with differing backgrounds. In order to meet the needs of a high proportion of non-traditional students, the College has extensive advising and developmental programs and relatively small classes in mathematics subjects, and encourages faculty to incorporate innovation in teaching. Even so, it has to be recognized that many students, even if nominally full-time, will find balancing the demands of coursework with work and personal obligations overwhelming. Mathematics courses, with the constant need to study for frequent tests, provide a particular challenge, unless students have sufficient commitment and motivation to prioritize the time and effort necessary for success. It is within this context, that I developed the self-reflection worksheet, as a tool to aid students in taking responsibility for their own progress.

The Self-Reflection Worksheet

The broad purpose of the worksheet is to motivate the student to self-reflect, so it is more than just a piece of paper or checklist to be filled in. It is designed as a structured basis for action by students, i.e. as a dynamic and integral part of the class. As I return each assessment (a graded test of which I give three per semester), I have students complete a self-reflection worksheet to revisit the assessment. I have had students complete the worksheet in class and in other cases, have had students return the worksheet two classes later. Students have given reflective answers in both methods. Through the worksheet students reflect on their knowledge of the material, their understanding of what was being assessed and the course

learning objectives, vent about the assessment, analyze their time management and study skills, and make concrete plans for improvement.

The worksheet questions are divided into four areas to aid student self-reflection: cognition, resource management, feedback, and self-action.

Cognition questions address student understanding of the material being assessed. It is crucial in mathematics classes that a student understands the material being assessed before he or she moves on to new material. Did the student understand what was being assessed? The student has a chance to review and relearn the material being assessed.

For each question on the test determine which section of the textbook it came from: Section 2.4, Section 3.1, Section 3.2, Section 3.3		
Problem #	Section	

Topics: constant multiplier, power rule, derivatives of sums and differences, derivative of a line, derivative of ln, derivative of e^x or e^{ax}, derivative of a^x, chain rule, product rule, quotient rule, derivative of trigonometric function		
Test Problem #	List all topics being assessed	I nailed it! OR I need to practice this more

Test Problem #	**Similar Problem page and # from the Review**	**Solve the similar problem correctly:**

Test Problem #	**Test Correction**	**Analysis: Why do you think you got the question wrong? Be specific.**

Figure 1. Cognition Questions.

Rate your level of understanding in the topics covered in Chapter 1 and in Sections 2.1,2.2, and 2.3:

Topic	I can do it!	I'm okay at this, I guess	I'm unsure/shaky about this	I have no idea about this
Sets of numbers (whole numbers, natural numbers, etc.)				
Adding and Subtracting Fractions				
Multiplying and Dividing Fractions				
Adding and Subtracting Positive and Negative Numbers				
Multiplying and Dividing Positive and Negative Numbers				
Properties of Real Numbers (Commutative, Associative, Identity, Distributive, Inverse, etc.)				
The difference between -1^2 and $(-1)^2$				
Terms (what is a term?)				
Combining Like Terms				
Solving Linear Equations using Addition/Subtraction and then Multiplication/Division				
Solving Linear Equations with Parenthesis in the Equation (having to use the distributive property and then combining like terms and solving the linear equation)				
Solving Linear Equations with Fractions				

Resource management questions "teach" students what learning resources are available to them. First year and developmental students are often deficient in their management of learning resources, and may not know how to study for a mathematics exam. Did the students use all the resources available to them to prepare for the assessment? Figure 2 shows resource management questions.

Figure 2. Resource Management Questions

Did you do the Review problems on WebAssign?			
All of them	Over 50% of them	Below 50% of them	None
Did you totally redo the problems on the lecture notes?			
All of them	Over 50% of them	Below 50% of them	None
Did you totally redo/do the problems on the homework?			
All of them	Over 50% of them	Below 50% of them	None

How did you study for this test?	
Redid all the problems on the quizzes and checked my answers	Yes or No
Did all the Review problems and checked the answers to the odd problems with the back of the ebook	Yes or No
Checked the answers to the even Review problems with a tutor in the Math Lab to make sure I did them correctly	Yes or No

Feedback questions allow students to express their opinions about the assessment and, provide information to the instructor about how the students feel. These questions give them an opportunity to give feedback on

the assessment, on the instructor, and on the course in general. Figure 3 shows feedback questions.

- Were there any problems on the test that you felt were unfair?
- If so, what made them unfair?
- Which problem did you feel was the toughest? Why?
- Were the questions on the test what you expected? If not, what did you expect?
- Do you feel you would have done better, worse, or the same (circle one) if you were able to use your calculator on this test?
- Did you have enough time to complete the test?
- Did you check over your test before you handed it in?
- Was the test:
  TOO HARD - HARDISH - MEDIUM - NOT TOO BAD - EASY (circle one)
- Was the material being tested:
  TOO HARD - HARDISH - MEDIUM - NOT TOO BAD - EASY (circle one)
- If you did badly on this test, what extra work would you suggest you do to bring your grade up?
- Are there any comments you would like to share with me about test and the course in general?
- Do you have any suggestions on how this course can be improved?

Self-action prompting questions. Now that students have self-reflected on their studying for the exam, their knowledge of the material being tested, and the exam itself, they must self-correct, and put together a plan for success based on their self-reflection. Figure 4 shows self-action prompting questions.

Figure 3. Feedback Questions

- Now that you have taken the test and seen your results, what would you do differently to prepare for this test?
- What was your score on TEST 1? _____
  What was your score on TEST 2? _____
  Did you do better on TEST 2?
  Why or Why not? Be specific.
- Did you study more for TEST 2 than for TEST 1?
  Why or why not?
- List some suggestions that could help you do better on the next test.

Figure 4. Self-Action Prompting Questions

Development of the Worksheet and Student Responses

It is important to stress that the worksheet is a tool, useful only to the extent that it facilitates post-assessment reflection and self-action by the student. Just to give out a piece of paper or a checklist would not do the job. Therefore as I continued to use the worksheet in my classes, and took account of student responses to it, I found it necessary to make adaptations. Even as I was trying to change the ways my students studied, the feedback from the worksheet helped me to explore ways to assist their self-reflection and learning. Each facet of the self-reflection process – cognition, resource management, feedback, and self-action – posed different problems.

Cognition

Cognition questions can simply ask a student to self-report understanding of a checklist of topics that were assessed or they can prompt the student to redo the problems that the student did not answer correctly. Results from my students showed that when students were asked to check off the topics on a list designating their understanding as "I nailed it, I kind of got it, or I'm not sure about this," the student did not really self-reflect. This did not motivate the student to actually review the material designated as "I'm not sure about this."

I found that when students were required to actually correct their work and explain why they got the problem wrong, they expended more effort and worked to find the correct answers. The problem was that while many students did rework the problems and reflected on why they did not solve the problem well on the exam (they explained their reasoning), a large number of students did not reflect at all. They either still did not answer the question correctly, showing that they did not understand the material, they copied the correct answer from a classmate without analyzing why and where they went wrong originally, or they wrote a large question mark in the space provided. These students did not self-reflect. I found that I was expending more effort to grade the corrections than many of the students did to write the corrections.

In order to remedy the difficulties with the reworked problems, I required students to find similar questions to the homework and classroom examples being assessed list and solve those problems. This was to

implicitly show students that the problems on the exam were very similar to the problems on the homework. Again, while some students did this exercise well and learned from it, a number of students did not follow the directions and either resolved the original problem on the exam or solved an unrelated problem that did not reflect their understanding of the topic being assessed. Thinking that perhaps students needed more guidance, I provided a table with the problem number on the test in the first column, the second column listed the topic(s) being assessed by that problem, and the third column listed a similar problem to the one being assessed, which all the students were required to work through. This strategy improved the reflection for most students. In order to get students to reflect on their cognition of the material, I found it best to require them to actually solve problems rather than just tick off a check list.

Resource Management

Having students reflect on their use of learning resources would seem to be more effective than lecturing or berating them for not studying. The answers to the questions on the use of learning resources can also be useful for the instructor, and I was able to use them both to follow up and revise the worksheet questions in this area. For example, I spent a number of hours putting together review problems, which were similar to the actual problems on the exam that students could work in advance of an exam. But the feedback from the test reflection after the exam was that fewer than half the class had attempted the review problems. And, of those students, fewer than half again had completed them all! In another example, I pointed out to the students that the question “how long did you study?” showed a correlation between length of study and success. Some students wrote they studied for a long time and then failed the test. I sat down with these students individually to see how they were studying.

Questions that elicit self-reflection on the management of learning resources included those about time spent studying in the math lab, time spent studying, number of review questions done, number of lecture note packets reviewed, and number of homework problems redone. A table of all the resources the instructor had available to be used to succeed on the subsequent assessment and a column next to each one for the student to check off if the resource was used and how much of it was used, was also be helpful for the student and the instructor. The list of resources is a gentle hint, again without lecturing, of what the students should be studying to

succeed. The feedback is valuable for the instructor to assess student use of the available resources. Instructors can then use this information to make sure students know exactly what and how to study for the next exam.

In this category are also important questions about consistent class attendance and distractions. Instructors only see students in classroom situations. But students have a large life outside of our classroom, and this needs to be acknowledged. Students can choose to share personal situations which are causing them to miss classes or to not fulfill their potential. The instructor can then meet individually with the student to help the student find ways to circumvent these distracters and succeed in the classroom.

Feedback

Questions on the worksheet included the difficulty of the material being assessed, the difficulty of the questions on the exam, the "fairness" of the exam, and the number of questions asked *vis a vis* the time allotted to complete the exam. It is important that students have a chance to voice their opinions about the assessment. This is cathartic for the student and beneficial to the instructor (for instructor self-correction). While the instructor may not agree with a student's assessment of the exam, it is important for the student to vent his or her feelings. I was able to meet with students individually to discuss these feelings before they exploded in the classroom. For example, if a test was too long for the time allotted, although I noticed this during the exam, a question on self-reflection following the exam about the length of the exam, gave a polite forum for students to express their frustration about this. The students then understand that the instructor cares about their learning and about their opinion about their learning, and is flexible and available.

Self-action

The final step is self-correction by the student. This is one of the most important aspects of self-reflection. The check list prompts the student first to think about what he/she would do differently to prepare for the next test, and then asks for a list of concrete steps as a plan to go forward. These questions are to help students to articulate their plan to succeed on subsequent exams. For example, several students commented that they had to work until quite late on the night before the exam. In the self-correction section of the worksheet, they vowed to take steps to ensure

that this would not reoccur before the next exam. Other students answered more generally that they would "study harder" for the next exam. In subsequent self-reflections I specified the need for concrete steps to improvement—what exactly will you study? When will you study?

Conclusions: Manifest and latent purposes

The worksheet, and subsequent follow up, gave students several opportunities:

- To **vent** and give feedback on the course after each test instead of only at the end of the semester;
- To rethink their **study habits;**
- To realize what they need to do to **succeed** in the course.

The worksheet also gave the instructor opportunities:

- To use it as a **diagnostic tool** to see what topics need reviewing and reassess the assessment;
- To **improve** the course by using feedback.

It would be nice to be able to assert that all these opportunities were seized, that all of the students self-reflected, and they all improved. Where researchers have analyzed data from students using self-reflection and similar techniques, the results have appeared positive, but not overwhelming so (Vasquez Mireles 2010; Zimmerman 2011; Bercher 2012). For my part, I found the worksheets useful as diagnostic tools and used the feedback to reflect deeply on how I could improve the courses and how I taught them. My experience, however, showed that the worksheet was not a magic bullet. Its usefulness in improving test results, not surprisingly, depended on variables such as individual commitment, study skills, motivation, external obligations, and willingness to honestly self-reflect. Students who took time to self-reflect did score higher on subsequent exams.

While improvement of the immediate test results was its manifest purpose, in the specific context in which I was teaching several other, latent, functions emerged from the broader student response:

- Just the exercise of filling out the post-assessment worksheet meant that students had to pause and think about the assessment, instead of simply discarding it;
- The worksheet indicated to students that the instructor was interested in them – their performance, their difficulties, their feelings – and wanted them to succeed;
- The worksheet opened up the possibilities of conversation, both on mathematical subjects and on their general progress with the instructor, whom they might otherwise feel to be unapproachable or distant.
- The worksheet indicated to students what they should study in mathematics, and various ways they should go about it;
- The process of reviewing and correcting problems the student got wrong or could not do, when it was completed, was especially valuable in enabling students to progress to the next level.

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