Demonstrating "What Right Looks Like" and Increasing Confidence in Math-Averse Students

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I. INTRODUCTION

A. BACKGROUND

As a math instructor of a mandatory calculus course, I see a wide variety of student performance throughout the semester. I was struck by the wide variety of attitudes held by the students, particulary the ones who struggled with calculus. Many of the lower-performing students often expressed their feelings that they "never get math" and lacked the ability to succeed in a calculus course. I also noticed that these students typically had extremely poor mathematical knowledge base, which manifested itself poor test performances.

In this classroom research study, I sought to see if I could somehow impact both of these characteristics of the lower-performing students. This particular group took my calculus course on the "off cycle;" that is, they were a semester behind their peers in their year group. Most of the students were behind because they lacked the fundamental skills necessary to begin the USMA Mathematics core course sequence, and were subsequently place in a class that reviewed the basic skills they would need to succeed mandatory 4-course sequence.

I wanted to see if I gave them more examples of "what right looks like" in a manner other than their textbook (which these students typically so ardently avoid), that they would be able to pick up and emulate the "correct" notation, and therefore be able to focus on truly understanding the deeper concepts in each lesson, instead of getting caught up in the notation and giving up. Likewise, if they were availed of a number of written solutions to problems on a regular basis, and they were able to compare and contrast their own work against these solutions, and find correctness in their work, their confidence in their abilities might increase. Is it possible to break the downward spiral of poor performance and subsequent low confidence in their abilities?

1. Math Anxiety and Confidence

According to [1], the psychological "habits of the mind" that we encourage students to form include attention to details and subtle distinctions, concentration over long

periods, checking for errors, misrepresentations, and bogus solutions, commitment to mastering technique, and self-reflection about patterns of error. Weak mathematics students, in particular, can have difficulty following a mathematics lecture because their skills are too weak to supply the details [1]. Stueben suggests that in order to "save" the weak students, teachers must emphasize skill and memorization.

At the same time, Polya teaches that real value of the study of mathematics comes from the process of struggling through a mathematical problem. "The teacher who wishes to develop his students' ability to do problems," he states, "must instill some interest for problems into their minds and give them plenty of opportunity for practice." We should naturally question and make suggestions to our students such that the student will eventually be able to use these questions and suggestions themselves [2]. This requires heavy concentration, however, and invites a level of learning and understanding which few students have time for unless a grade is involved. The grading process, through examinations, is particularly taxing for math-averse students.

A difficult question to answer is whether math-averse students are poor test-takers because they lack mathematical understanding, lack confidence, or because they have high math-test anxiety. A lack of confidence in math that undermines academic performance (or "Math Anxiety") may occur because students feel they are dealing with many foreign concepts and procedures [3]. The anxious students have a disrupted "working memory" as a result of their anxiety, which means that their capacity to retain information while working on a task and, at the same time, block out distractions and irrelevant information, is disrupted [3].

High test-anxious students report low perceptions of control and low expectancies, reflecting achievement and academic emotions that are directly related to academic settings, such as classroom instruction and completing tests and exams [4]. (Pekrun's control-value theory of emotions defines these "achievement emotions" and "academic emotions" to describe emotions experienced in achievement and academic contexts [5].) Researchers theorize that higher cognitive ability should outcome with more positive academic emotional experiences because high cognitive abilities typically coincide with good academic achievement outcomes [4]. Further, previous positive performances can influence future academic emotional experiences. Goetz suggests that teachers can foster a sense of control

in their pupils, which, as a result, should have a positive impact on their academic emotional experiences, by administering exams that are well-structured and clearly delineate the goals and expectations set for the students [4].

Research suggests that there are three phases of test completion, summarized as follows: [4]

1. the forethought phase in which students prepare for the test,
2. the performance phase during which students actually take the test, and
3. the self-reflection phase in which students reflect on the test and make sense of the results.

Students with poor study skills have been "noted also to be inadequate in the self-monitoring during the test preparation phase [6]" and are likely to overestimate their preparedness for exams. This can "lead to a false sense of security during the test preparation phase, limiting the overall preparation by the student, which will naturally adversely impact performance [7]." On the other hand, weaker students who have low confidence in their abilities are likely to adopt "performance-avoidance goals" which manifest through procrastination [8].

In the self-reflection phase of an exam, research suggests that high-anxiety students either view failure as caused by an internal source that cannot be overcome (for example, low intelligence or poor memory), or by an external source that is beyond their control (unfair testing practices, difficult material, or poor instructional support) [7]. Either way, these feelings can lead to further avoidance behaviors, damaging any potential for success on future tests. The optimal way of helping these high-anxiety students, and breaking the downward spiral of poor performance and increased anxiety rests in "targeting their affective orientations as well as helping them develop adequate test preparation and adaptive coping skills [7]." This might involve "effective goal setting, test preparation skill development, scaffolding for students as they prepare for exams, emotional or motivational support from peers or instructors, helping students develop and maintain realistic performance attributions, and training on emotional self-regulation during stressful experiences [7]."

2. Providing the "Answers"

There is a growing body of research and discussion about successful online classrooms and appropriate use of electronic learning resources. While a standard classroom, particularly a mathematics classroom, can rely on a textbook for their material, we can still create additional material to help concepts come to life. The key to this material is creating material that truly helps students understand the concepts [9]. Information that students can use and reuse as many times as they please can help students visualize and understand more abstract concepts. Some instructors of who have enhanced their courses with online material report how much it benefits students to have an additional aspect of control over their learning process [10]. Further, when students have access to online materials, students tend to come to class more prepared [10]. To be effective the resource pool from which students can pull should be targeted, organized, to-the-point, effective, and credible [11].

Some research has been conducted that indicates that when students are presented with the opportunity to bring and use notes to an examination, students with high test anxiety demonstrate inferior skills in selecting notes to be used [7]. Notes that can be classified as "copied definition notes" (mechanically reproduced, either from fellow students or from provide online lecture materials) in the absence of personally-generated notes, greatly inhibit the learning or performance benefits that these materials can provide [7][12].

II. METHODOLOGY AND RESEARCH PLAN

Prior to nearly each lesson of the semester, I developed a classroom worksheet to hand out to students. The intent was not to provide them a piece of paper upon which to take notes; rather, it was to provide a pool of problems, some of which I would cover in class, to which they could receive immediate feedback about the accuracy of their solutions as they attempted to complete the worksheet following the lesson. The solutions, as written, were as thorough as possible–explaining every step, so that a student could follow the work every step of the way. I made careful note to format the solutions the way that I would want to see the solution written on a WPR.

I posted my handwritten solutions and any computer-generated support files (typically Mathematica commands used to solve the problem) as scanned .pdf documents on Blackboard, and tracked how often each student accessed these files through the Blackboard option to collect statistics on the item.

Following the first and second Written Partial Reviews (WPRs), and after students had an opportunity to attempt the problems again in a non-stressed environment, each was given a questionnaire to complete (See Appendix A) that surveyed the students' knowledge of, use of, and opinion of the posted handout solutions. Five main ideas were reported on this survey that I used in my analysis here.

Download Solution Level (When did you download the solutions?)	Found helpful in daily study?	Increase confidence going into the exam?	Did it help during the exam?
3 - Right away	3 - A great deal	1 - Yes	1 - Yes
2 - Sometime after (within 2 days)	2 - Somewhat	0 - No or N/A	0 - No or N/A
1 - Right before the WPR	1 - Not at all		
0 - Never			

I analyzed the survey data, WPR scores, and the collected statistics gathered from the Blackboard system to see if I could find any improvement in examination scores between my students, who had access to these handouts and solutions, and the other students taking the course, who I am assuming did not. It is possible that this is a flawed assumption and may introduce error into my analysis - I learned in teaching this particular group of

students that they are particularly close-knit. As a small population of their class who did not take the first core math sequence course as first-semester freshmen, many (about 70 students distributed over 5 sections) had been in the same classes together for three semesters, now, and were accustomed to working together and pooling resources.

In order to make sense out of a mountain of Blackboard data, I decided to ignore the item-specific data for each daily handout. Instead, I considered what I call each student's "Blackboard Access Level", or BAL. Each time that a student accessed the documents I posted, Blackboard would count that the student had accessed the material one time. However, I found that the number of times a student might access the site each day ranged from zero to forty times a day, making it difficult to discern a level of use of a student who accessed the data one time, and left the file open, from one who transferred back and forth from other documents multiple times (each time, adding a "count" to Blackboard's tally). I determined a student's BAL by counting the total number of days that they accessed Blackboard at least one time, and dividing that number by the total number of days possible to access Blackboard in that particular block of instruction (three blocks total). This provided a basis of comparison upon which to determine relative access levels between students. (The other students in the course who I did not teach received a BAL of zero.)

Additionally, I wanted to observe if the practice of posting these solutions increased the confidence level of my students and see if it made them feel better about the process of studying for and taking an examination.

III. RESULTS

While I received nothing but positive feedback from students about the practice of posting solutions to the class handouts, it had no impact on their performance on any of the WPRs over the semester.

A regression analysis of each WPR1 score vs. the BAL during the period prior to that WPR reveals the results shown below:

Regression Analysis: WPR1 Score versus BAL WPR1

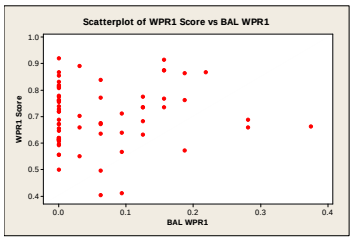
The regression equation is
WPR1 Score = 0.693 + 0.142 BAL WPR1

Predictor	Coef	SE Coef	T	P
Constant	0.69253	0.01706	40.60	0.000
BAL WPR1	0.1417	0.1671	0.85	0.399

S = 0.115735 R-Sq = 1.1% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.00963	0.00963	0.72	0.399
Residual Error	67	0.89743	0.01339		
Total	68	0.90707			



Regression Analysis: WPR2 Score versus BAL WPR2

The regression equation is
WPR2 Score = 0.761 + 0.113 BAL WPR2

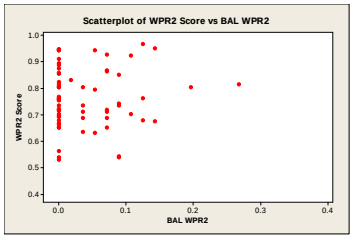
66 cases used, 3 cases contain missing values

Predictor	Coef	SE Coef	T	P
Constant	0.76140	0.01722	44.21	0.000
BAL WPR2	0.1134	0.2505	0.45	0.652

S = 0.113722 R-Sq = 0.3% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.00265	0.00265	0.21	0.652
Residual Error	64	0.82769	0.01293		
Total	65	0.83034			



Regression Analysis: WPR3 Score versus BAL WPR3

The regression equation is
WPR3 Score = 0.700 + 0.145 BAL WPR3

Predictor	Coef	SE Coef	T	P
Constant	0.69969	0.01658	42.19	0.000
BAL WPR3	0.1447	0.1266	1.14	0.257

S = 0.105464 R-Sq = 1.9% R-Sq(adj) = 0.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.01452	0.01452	1.31	0.257
Residual Error	67	0.74522	0.01112		
Total	68	0.75974			

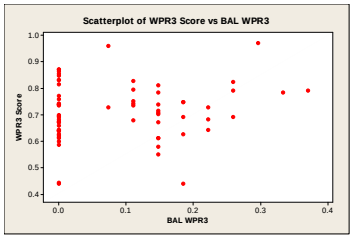


Figure 1. Linear Regression Results: WPR Score as a Function of BAL

As we can see from the scatterplots of the data, there is no indication that an increase in BAL results in an increase in WPR scores. Likewise, the regression analyses

large p-values indicate that there is not sufficient evidence to conclude that the WPR score is dependent on the BAL. The p-value does get smaller for WPR3, which might indicate more of a relationship between BAL and WPR scores later on in the semester, but the p-values are still very, very large, indicating that the relationship does not exist.

Likewise, a two-sided t-test between the WPR scores of the handout-using students versus the non-handout-using students, shown in Figure 2, indicates the same lack of relationship. Again, the p-values got smaller as the year progressed, indicating that the potential difference between the means of the two groups became larger, perhaps as students learned how to use the handouts and solutions more effectively.

Two-Sample T-Test and CI: BB Users - WPR1, Non BB Users - WPR1

```
Two-sample T for BB Users - WPR1 vs Non BB Users - WPR1

                   N   Mean  StDev  SE Mean
BB Users - WPR1   33  0.699  0.130    0.023
Non BB Users - W  36  0.703  0.103    0.017


Difference = mu (BB Users - WPR1) - mu (Non BB Users - WPR1)
Estimate for difference:  -0.003758
95% CI for difference:  (-0.060412, 0.052897)
T-Test of difference = 0 (vs not =): T-Value = -0.13  P-Value = 0.895  DF = 60
```

Two-Sample T-Test and CI: BB Users - WPR2, Non BB Users - WPR2

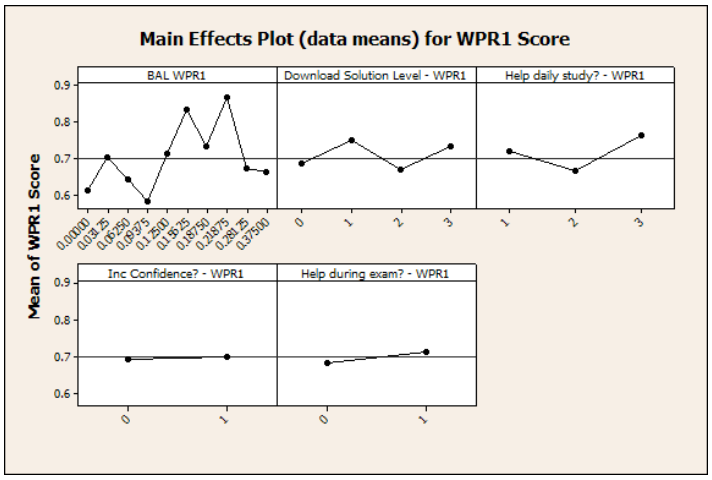
```
Two-sample T for BB Users - WPR2 vs Non BB Users - WPR2

                   N   Mean  StDev  SE Mean
BB Users - WPR2   33  0.758  0.114    0.020
Non BB Users - W  36  0.768  0.113    0.019


Difference = mu (BB Users - WPR2) - mu (Non BB Users - WPR2)
Estimate for difference:  -0.009727
95% CI for difference:  (-0.064276, 0.044822)
T-Test of difference = 0 (vs not =): T-Value = -0.36  P-Value = 0.723  DF = 66
```

Two-Sample T-Test and CI: BB Users - WPR3, Non BB Users - WPR3

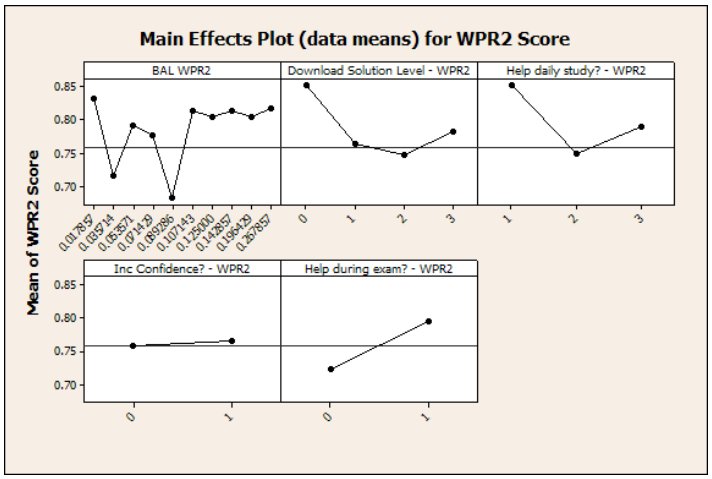
```
Two-sample T for BB Users - WPR3 vs Non BB Users - WPR3

                   N   Mean  StDev  SE Mean
BB Users - WPR3   33  0.724  0.105    0.018
Non BB Users - W  36  0.701  0.107    0.018


Difference = mu (BB Users - WPR3) - mu (Non BB Users - WPR3)
Estimate for difference:  0.022758
95% CI for difference:  (-0.028133, 0.073648)
T-Test of difference = 0 (vs not =): T-Value = 0.89  P-Value = 0.375  DF = 66
```

Figure 2. Two-Sample T-Tests Between Handout-Using Students and Non-Handout-Using Students

But what about the other, less-tangible benefits of this approach? A main-factor analysis of the means of the data (data for my classes only) yields the following main-effects plots for the periods prior to the first and second WPRs (the third WPR's survey data was not yet available at the time of submission of this paper):



(a) Post-WPR1 Survey Results



(b) Post-WPR2 Survey Results

Figure 3. Main Effect Plots

These effects plots indicate that there may be a mild correlation between students who delineated the handout solutions as very helpful vs somewhat helpful, in that those who indicated the solutions were very helpful had a slightly higher WPR average for both WPR1 and WPR2. It is interesting, however, that students who indicated the solutions were not helpful at all had higher scores than those who answered "somewhat helpful," to a great

extent, especially for WPR2.

Disappointingly, there is only a minuscule increase in average WPR scores of students who indicated that their confidence was helped.

There also seems to be a slight trend in the students who found the handouts to be helpful in their daily study. Those who reported that it was very helpful did, in fact, have slightly higher WPR scores than those who found it somewhat helpful. Interestingly, though, those who reported that it was not helpful at all ALSO scored higher than those who found them somewhat helpful.

While the statistics indicate that this experiment failed, I received overwhelmingly positive feedback from students when I asked them to explain their answers on the survey. The most common and insightful comments I received are summarized here:

Question: In general, do you like the fact that the solutions are posted? Why?

- "It's almost like a self-AI. It's seeing the answer as the "P" would explain it without having to actually schedule an AI session for it. (Although judging by my last WPR I should.)"
- "It shows that the math department is working on behalf of the student to provide them with every possible advantage."
- "It helps me better understand the material."
- "I can check my work and it is a confidence booster if I am right."
- "...it gives us an opportunity to see the solutions worked out and we can see where we made the mistake."
- "It helps when I go back to my room and I am stuck."
- "Allows me to see what right looks like."
- "This idea that you have works really well. For me personally it serves as concentrated and enhanced way of rehearsing the material and see its applications at the same time. This however causes one problem though. There is less motivation to do the problems, because nobody hasfree time as it is and knowing in the back of your head that there are approved solutions on anyway cadets get relaxed."

Question: To what extent do you feel that looking at the solutions helped you understand the class lesson objectives? Explain.

- "The solutions on Blackboard help me a lot. They're the best review tool I use because it gives example problems but also shows the answer and how to get it to make sure I have the concept down. Having solutions on Blackboard let me pay attention to the method of solving a problem in class instead of concentrating of copying down the solution."
- "It just gives me a place to go when I get stuck, which is nice not to have to go in for AI every time I have a question."
- "If I paid attention in class the solutions helped me a great deal, however, if I did not pay attention looking at the solutions still helped but not as much."
- "I still had to learn the material. Seeing the answer would not give me a clear way to solve the solution but it definitely put a foot in the door for me."
- "If there is anything that is still somewhat unclear after class, or particularly when there are things that I didn't think to ask until looking at the problems after having thought I understood in class (but realize I don't afterwards), the solutions are an amazingly efficient supplement for AI when you have a very tight schedule."

Question: Did you find that having the solutions on your computer helped you during the exam?

- "They helped some, but not as much as I had thought they would. It is possible that I was looking in the wrong places during the test."
- "I didn't use them because I thought I would waste time looking for something in the solutions rather than trying to actually do the problem."
- "Even if the problem was different, if you had downloaded the bulk of the problems, there was a good chance you had a problem that was similar to anyone we would be tested on. Still had to know how to manipulate the problems and know how do to them. And not enough time."
- "It gave me more confidence and at the same time, it allowed me to find some solutions."
- "It was good to have an example that you knew was correct in front of you, instead of notes from a classmate."
- "I feel that having the solutions on my computer did not help me. This is because there was too much information over a bunch of files. I think they did not help me because I did not review them enough. That is why I had a time crunch."

- “I found it hard to find a good example quickly under time constraints. I relied on open-notes too much.”

IV. CONCLUSION AND FUTURE WORK

The survey responses reveal both some immature and mature perspectives on learning and test-taking. Clearly, some students used the worksheets in the way that I intended - as a study tool, and not as a reference during the exam, but some used them as a crutch from which to "find the answer" to an exam problem, leaving them disappointed, with not enough time to finish the exam (a common problem). It is possible that my section's exam scores improved over the rest of the course's scores in the final WPR because my students did finally learn how to best use the tools I provided them. Still, I'm left to conclude that the art of improving academic achievement among a population of largely uninterested students does not lie in the technique discussed here. While their scores may be no different than that of their peers, the act of forcing my students to recognize the tools available to them and to reflect on how they use those tools in their test-preparation process seemed to increase their level of satisfaction, if not confidence, as they left the course. I believe that many of them now realize that sometimes, even if the "answer" is right in front of you, it does no good unless you've prepared yourself wisely to retrieve that information.

The work involved with creating these worksheets was not insignificant, but not difficult, especially now that they are complete. As I watched my students in classes over the semester, I noted a strong lack of note-taking skills. There may be room to modify the existing worksheets such that they scaffold the note-taking process as well, instead of just problem repositories.

Appendix A

MA205 - Integral Calculus
Survey

This survey is being used for my own research into classroom teaching techniques. Since I will be doing some statistical analysis with your responses, this is NOT an anonymous survey. Your responses will in NO WAY impact my evaluation of you in this course. Thank you for your honest feedback!

1. Last Name:
2. From the beginning of the course up to the 1st WPR ONLY, *were you aware* that the solutions to the class problems handed out in class were posted on Blackboard?
3. From the beginning of the course up to the 1st WPR ONLY, did you *look at* any of the classroom handout solutions that were posted on Blackboard?
4. From the beginning of the course up to the 1st WPR ONLY, did you *download to your computer* any of the classroom handout solutions that were posted on Blackboard?
5. When did you typically look at or download the solutions?
   (a) As soon as they were posted (within 2 days)
   (b) Sometime after they were posted, but before the WPR
   (c) Right before the WPR
   (d) Other (explain):
   (e) Not applicable; I didn't look at the solutions
6. How would you rank the readability/clarity of the solutions?
   (a) Easy to follow; I could understand how the solution was developed.
   (b) Kind of understandable, but I still had to work hard to see where the solution came from.
   (c) I didn't understand the solutions at all.
   (d) Other (explain):
   (e) Not applicable; I didn't look at the solutions
7. In your daily class preparation/study, to what extent do you feel that looking at the solutions helped you understand the class lesson objectives?
   (a) A great deal
   (b) Somewhat
   (c) Not at all
   (d) Other (explain):
   (e) Not applicable; I didn't look at the solutions

   Please explain your response above:

(a) Page 1

8. *Before* the WPR, did you feel that having the solutions downloaded to your computer were going to help you on the exam?
   (a) Yes
   (b) No
   (c) N/A; I did not download the solutions to my computer.
9. *Before* the WPR, did you feel that having looked at the solutions increased your confidence in your upcoming performance on the WPR?
   (a) Yes
   (b) No
   (c) N/A; I did not look at the solutions.
10. *After* the WPR, did you find that having the solutions on your computer helped you during the exam?
    (a) Yes
    (b) No
    (c) N/A; I did not download the solutions to my computer.

    Please explain your answer (if you responded "Yes" explain why they helped you, if "No" explain why they did not help you):
11. In general, do you like the fact that the the solutions are posted?
    (a) Yes
    (b) No

    Why?
12. In the 2nd block of instruction, will you be doing anything different with respect to the posted solutions?
    (a) Yes
    (b) No

    Why?
13. Is there anything else you would like to tell me about the practice of publishing solutions to class problems?

(b) Page 2

Figure 1. Survey Given to Students after WPR1

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