Facilitation of Student-centered Formative Assessment using Reflective Quiz Self-corrections in a Calculus Physics Course

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ABSTRACT

Calculus Physics I is a calculus based general physics course covering fundamental principles of mechanics. The overwhelming majority of students in this course are prepared for admission with advanced standing to a Bachelor of Science engineering program. Often found in the classroom are that many students have difficulty in solving problems, skills that are crucial for students to be successful in this rigorous curriculum. In spite of using active engagement learning approach, showing plenty of examples, asking students to practice problems during the class time and having students do their homework every week, we still found quite a few students cannot solve similar problems in the tests so that they choose to withdraw from the class. Is there anything we can do to encourage students to remain in the class and help them learn better? Weekly student-centered formative assessment using reflective quiz self-corrections is a powerful solution to this problem. Pedagogy researches have been focused on student-centered learning inside classrooms, little attention has been paid to how formative assessments outside classrooms can support student learning, improve outcomes and actualize the drive for lifelong learning in engineering programs. In this grant-funded research project, once-a-week quiz was given in class to ask students to solve one problem. Quizzes were graded with no details. Without given solutions, students were then asked to conduct reflective self-corrections on each quiz that they did not receive full credits. It was possible to increase their quiz scores up to full points if students successfully completed the required tasks. The following data were collected for analysis: two rounds of a perception survey related to the learning of physics and a survey particularly designed for reflective quiz self-correction activity; a pre- and a post-

mechanics baseline test at the beginning and the end of the semester plus two tests and one final exam; quiz mistake categorization reports. Feedback from students was overwhelmingly great. This practice not only promotes students self-regulated learning but also helps them study consistently. Students learn much better from finding their own mistakes and score higher in exams. Therefore, they become more confident and are more motivated to remain in the program.

I. Introduction

Over the last few decades, there has been a great amount of change in the way about how students learn in higher education. Instead of characterizing it as a simple acquisition process based on teacher transmission, learning is now more commonly considered as a process where students become active learners and teachers become facilitators who help them to construct their own knowledge and skills (Barr & Tagg, 1995; Decorte, 1996; Nicol, 1997, 2006). In Physics Education Research (PER), active-engagement strategies have been widely adopted and have shown to be one of the most successful methods of improving students' learning experience. These researches have been focused on student-centered learning such as inquiry based learning, peer-instructions as well as developing and implementing innovative learning materials inside classrooms. However, it is worthy to point out that in this very important higher education innovation process, little attention has been paid to assessment, which is an important part of learning, not to mention student-centered assessment outside classrooms.

Assessment is to judge how well students perform. (Knight 2006) Nowadays, assessments are seen as the responsibilities of teachers and are still largely controlled by teachers; and feedback is still generally seen as a transmission process. (Sadler, 1998; Boud, 2000; Yorke, 2003) Usually teachers communicate feedback messages to students about what is right and wrong, about its strengths and weakness in their academic work, and students in the hope will utilize this information to make improvements. (Nicol, 2006) Two types of assessments are generally used. Summative assessment is used to summarize students' achievements in order to award some kind of certification. Formative assessment refers to all the activities undertaken by teachers and by their students in assessing themselves to provide information to be used as feedback to modify teaching and learning activities. (Black, 1998) Three main problems about assessments are pointed out in the article named "Working inside the black box: Assessment for learning in the classroom" (Black, 2004): a. the assessment methods that teachers use are not effective in

promoting good learning; b. grading practices tend to emphasize competition rather than personal improvement; c. assessment feedback often has a negative impact, particularly on low-achievement students, who are led to believe that they lack ability and so are not able to learn. Therefore, it is urgent and important to find practical ways to improve assessment methods and utilize them to better serve students' needs. The integration of instruction, learning and assessment should be emphasized.

Fortunately there has been some active research regarding how formative assessments can support learning, improve outcomes and actualize the drive for lifelong learning. (Clark, 2012) These research are mainly carried out in disciplines such as English (Wei, 2010), Criminology (Gijbels, 2006), Medical curriculum (Weurlander 2012) or conducted with Primary and Secondary learners (McLaren 2012). Some inside classroom formative assessment activities such as Clickers (Majerich, 2011) and Assessing-to-Learn (Dufresne, 2004) are investigated in Physics. On the other hand, evidence is provided in an article by Laverty etc. (Laverty, 2012) that increasing the number of exams (summative assessments) in fact does lead to better learning success, less cheating and guessing on homework, and better students course evaluations. Student-centered outside classroom assessment activities are rarely seen in any disciplines although it is pointed out that more practices on student-centered formative assessment activities should be seen. (Nicol, 2006) Educational literature in various disciplines such as physics and mathematics has shown the importance of self-reflective activities in science courses. (May & Etkina 2002; Zimmerman & Kitsantas 2005) One way of engaging in reflective activities is through self-corrections of homework and exams. (Guo & Vazgen 2012; Henderson & Harper 2009; Ramdass & Zimmerman 2008) In particular, Henderson and Harper described a few physics classroom experiments where self-reflection activities have been used. The results are more than encouraging. However, these experiments are focused on conceptual understanding of physics in a four year college. Little research has been done on student problem solving skills in a community college setting. By saying that, we have to consider that community college students are different from those from colleges under a selective admission policy. When we consider student learning outcomes, we must factor in the under-preparedness of our students, the low socio-economic structure of the populations we serve, the significant impact on adults with their complicated lives and competing interests. (Marti 2009) It is worthy to mention that reflective homework self-correction activities as part of a conceptual physics course were

successfully incorporated in a community college setting. (Guo & Vazgen 2012) The reflection activity showed positive impact on student conceptual understanding of physics and was very welcomed by the students. As a continued study, in this article, we will present a practical and powerful tool to use for both teachers and students: a weekly outside classroom student-centered formative assessment activity using reflective quiz self-corrections. It is investigated in a community college setting for a calculus based general physics course covering fundamental principles of mechanics focusing on problem solving skills. It is shown that this formative assessment method is effective in promoting good learning, personal improvement and self-esteem. It can be easily implemented and put into practice together with any other innovative classroom pedagogy because assessments should no longer merely be seen as something separate from instruction, administered at the end of the learning process, but also as a powerful tool for promoting deep learning activities. (Dochy & McDoweell, 1997; Sambell et at., 1997) It serves as a good feedback exercise and a useful formative assessment model to be applied not only for physics but also for any other disciplines.

II. Description of the study

Calculus Physics I PH411 is a calculus based general physics course covering fundamental principles of mechanics. It includes kinematics, classical laws of motion, statics, conservation laws, work, mechanical energy, and simple harmonic motion. The overwhelming majority of students in this course are prepared for admission with advanced standing to a Bachelor of Science engineering program. The Engineering Science curriculum is a cooperative offering of the engineering technology, science, and mathematics programs. It is often found in the classroom that many students have difficulty in getting started with a given problem, applying appropriate concepts and principles, let alone solving problems. These problem solving skills are crucial for students to be successful in this rigorous curriculum. In spite of showing plenty of examples, asking them to practice problems during the class time and having them do their homework every week; professors still find that quite a few students cannot solve similar problems in the tests so that some students choose to withdraw from the class. Once in a semester, 8 out of 27 students withdrew from the class and 5 more got INC. Many students in this class are motivated to learn and want to get better grade, is there anything we can do to encourage and help them learn better?

It is true that physics professors conduct a number of assessments such as quizzes and/or exams each semester. They often spent a huge chunk of time to grade these assessments and are willing to again invest a significant amount of in class time to discuss solutions extensively and post them online in the hope that students will compare the solutions with their own, learn from their own mistakes and avoid making any similar mistakes again in the future. Unfortunately in reality, it is commonly known that most students do not make full use of the learning potential of these assessments. (Henderson & Harper 2009) They either look at these solutions superficially or simply are discouraged by their bad scores hoping to see a better grade next time or choose to withdraw from the class or simply change their majors to avoid taking physics. Quizzes/exams are thought by students as a report for their performance but not chances to improve their learning, professor's time in some means are wasted.

The typical PH411 Calculus Physics I course has four 50-minute lectures and one 1 hr 50 minute long laboratory per week. The official textbook for the course is "Fundamentals of Physics" by David Halliday, Robert Resnick and Jearl Walker. Besides regular lectures covering basic concepts and principles, plenty examples were shown in class and plenty opportunities were given to students to practice. Approximately ten problems were assigned as homework and solutions were posted online one week afterwards. Two tests were administered during the semester plus a final comprehensive exam. They were all composed of certain number of problems (4-6 problems). Once-a-week popup quiz was given in class to ask students to solve one problem. Quiz then was graded and given back to students as soon as possible.

In order to promote student-centered formative assessments in the hope students will see these activities as opportunities to learn instead of just evaluations; we did all the above activities except that quizzes were first graded with no details. Each student was given a folder to keep their quizzes for the whole semester. They were required to perform reflective self-corrections on any quiz which they did not get full points on. Students had 2-3 days to complete the assignment. If they complete the activity, students could improve their quiz score by up to full points. If they do not do it, they will lose all the points. It is worthy to mention that quiz scores account for 30% of the final letter grade. To receive credits for their reflective self-corrections, they need to finish the following three steps for each problem. A. Diagnosis step to identify where the mistakes are; B. Generalization step to learn from their mistakes by generalizing beyond the specific problem;

(Henderson & Harper 2009) C. Production step to generate a new solution using the problem solving strategy provided (**Read→ Draw→ Label → Identify → Equations → Solve→ Substitute→ Check** (Serway, Vuille&Faughn, College Physics textbook). Quizzes were re-graded again and solutions were posted online afterwards. This activity was performed for every quiz. During the whole semester, students were also asked to conduct mistake categorization exercises twice, in which they needed to, reflect over the mistakes they had made in their solutions and to think of category names for different types of mistakes they had made. They were given a table to complete. The category names should be written in the first column of the sheets provided. Students could create as many categories as they wish. In the second column they should provide a brief description of each category name. In the third column, students were asked to write down those problem numbers where they had made such mistakes in solutions that correspond to their category descriptions. A problem could be placed in more than one category created by them.

The following data were collected for analysis: two rounds of a perception survey related to the learning of physics and a survey particularly designed for reflective quiz self-correction activity; a pre- and a post-mechanics baseline test at the beginning and the end of the semester plus two tests and a final exam (quizzes and exams are the same as what were used in the previous semester without this intervention); two quiz mistake categorization reports.

III. Results, Discussions and Conclusions

Some sample materials used and data collected from the project are given below.

Sample quizzes questions:

Example 1: A car moving with constant acceleration covered the distance between two points 60.0 m apart in 6.00 s. Its speed as it passed the second point was 15.0 m/s. (a) What was the speed the first point? (b)What was the magnitude of the acceleration? (c) At what prior distance from the first point was the car at rest? (d) Graph x versus t and v versus t for the car, from rest.

Example 2: A rifle is aimed horizontally at a target 30 m away. The bullet hits the target 1.9 cm below the aiming point. What are (a) the bullet's time of flight and (b) its speed as it emerges from the rifle?

Sample categories of mistakes given by students in Fig. 1 as follows:

Your task is to reflect over the mistakes you have made in your solutions and to think of category names for different types of mistakes you have made. The category names should be written in the first column of the sheets provided to you. You can create as many categories as you wish.

In the second column please provide a brief description of each category name.

In the third column, please write down those problem numbers where you have made such mistakes in solutions that correspond to your category description. A problem can be placed in more than one category created by you.

Write down your category names in this column	**In this column write a brief description of the name of each category**	**List the problem numbers that has mistakes in solutions that fall into the category**
units	units are very important in solving problem. Incorrect units will result in incorrect answers	Quiz #5 Quiz #1, 3
Illustration/Drawing	Incorrectly drawn graphs or illustrations of whats happening in the problem will confuse you and there's a big chance of setting up the problem incorrect which will result in a wrong answer	Quiz #3, d
calculations	calculations are very critical and since a calculators is always used to solve problems, you should always double check calculations.	Quiz #5
Determining Forces/xy Components	Always pay attention to which direction Forces are going & if certain forces needs to be split into x & y components. This is also important when it comes to solving problems.	Quiz #8, C Quiz #6 Quiz #4, a, b, c, d, e
unanswered questions	Never leave anything blank, always attempt to solve	Quiz #8, e

Test1 Ave		Test2 Ave		Final Ave		Withdrawal Rate	
57	61	48	54	41	44	41%	22%

Table1: Comparison between the grades for Test1, Test2, Final and Withdrawal Rate using the same testing materials. The second number in each column is the result after reflective quiz self-corrections.

As you can see from the above table, all the tests grades have been improved and withdrawal rate has been significantly dropped. Students were much more willing to stay. 90% of students expressed that they liked to do this activity. One student mentioned that it was boring but helpful. The other one said he did not like it because he felt like it was an extra homework. Among those who appreciated this activity, when we asked "if you did not do quiz reflection in this class, would you be a different learner?" 20% students answered no. One student pointed out that he already has a set of methods of how he learns. Regardless, he still learns the way he knows the best. However, the rest who answered yes spoke very highly of this activity. These students include repetitive learners, ones who would come to office hours often, ones who prefer lots of practices, and ones who are scared of physics. One student commented that "this is the first class I have ever taken that required a reflection. So I would have to say that it did help." Others said that he would probably make the same mistakes over and over again without knowing it or he would have come to office hours more often or the quiz reflections were more in depth than just memorizing or he would make things a lot harder simply because he would not get that chance to discover what he did wrong. We are planning to conduct a finer-grained analysis of students' responses to investigate the impact of the intervention on students' problem solving skills. The analysis of the intervention impact on students' scientific attitude is in progress as well. More data analysis and research will be done on how students categorize their mistakes and how different professors would have categorized instead.

The article titled "Formative assessment and self-regulated learning: a model and seven principles of good feedback practice" argued that higher education should build on the ability of students to assess their own work and generate their own feedback. Students should be more proactive rather than reactive when carry out formative assessments. (Nicol D. and Macfaarlane-Dick D. 2006) Seven principles of good feedback practice to facilitate self-regulated learning

presented in this article are: a. to help clarify what good performance is; b. to facilitate the development of self-assessment; c. to deliver high quality information to students about their learning; d. to encourage teacher and peer dialogue around learning; e. to encourage positive motivational beliefs and self-esteem; f. to provide opportunities to close the gap between current and desired performance; g. to provide information to teachers that can be used to help shape teaching. In the end the authors also mentioned that the research challenge is to refine these principles and to gather further evidence about the potential of formative assessment and feedback to support self-regulation. From our study in this project, it is shown that reflective quiz self-correction activity indeed is a good feedback practice, which is a practical and a powerful tool to use for both teachers and students.

When the quiz was first graded without details, students learned about what good performance is based on their rubric score. Then they were given chances to assess themselves. Sometimes it was pretty easy for them to find where the mistakes are. However, sometimes they might need extra help to identify what went wrong. This process is very important because in this process students become an active learner where they must use their brains to seek information and apply it to regulate their learning. They have to either perform reflection on their work or they need to go after feedback from classmates, tutors or professors, which open up a dialogue among students or between students and professors. Once they corrected their mistakes either by themselves or with some help, they were rewarded with credits and realized what kind of mistakes they made in the hope that they will not make it anymore. In the meantime, students started to realize it is not as hard as they thought. They are able to do it, it is not because they do not have this ability or intelligence to do it, and it is simply due to the fact that they did not put enough effort or used the wrong strategies. Anyone can achieve something as long as he believes it and he tries to work on it. This practice also provides opportunities for students to close the gap between current and good performance by redoing the quiz and generalizing mistakes. There is no competition here; it is all about personal improvement. When they produce their new solutions, problem solving strategies were emphasized and students were trained over and over again throughout the whole semester. Furthermore, students were also given chances to report mistake categories so that they can have a big picture about themselves especially the type of mistakes they have made which can be avoided in the future. On the other hand, it also helps

professors understand better about their students, their difficulties and their progress so that they can adapt their teaching accordingly.

In conclusion, the reflective quiz self-correction practice as a way of formative assessment method does not focus on tests but on students learning. It helps to promote self-regulated learning where students are aware of their own learning so that they are motivated to study consistently. This is especially important for community college students when they are loaded with family responsibilities and work. Overall, students loved the opportunity of recovering quiz grades, they appreciated self-corrections' positive impact and many of them are even motivated to continue this activity after this course. These again are evidenced by the following feedback samples from students' surveys at the end of the project.

Sample students' feedback:

Question1: Did you like doing quiz reflections? Why?

Yes because it had helped me out what equation to use for a question.

Yes, I feel like it's a 2nd chance to improve the grade.

Yes because it tells me what my mistakes were and forced me to think about those mistakes. A good study and learning tool.

Yes, it gives me a chance to correct my mistakes and never make those mistakes in the future.

Yes, it enabled me to understand the problem in a different approach.

Yes, it helps me get a better understanding of what we were learning.

Yes, rather than getting back to the missing points, you are able to reflect on what you did wrong and learn from it.

Question2: What do you think you gained from doing quiz reflections? Please give examples.

If I do not have to do the reflection, I might not try to figure out the right answer to the problem and throw the quiz away.

I gain the ability to learn from my mistakes and learn what to do when I encounter similar problems.

More time studying; understanding the solution; learning from my mistakes; having the opportunity to gain full credits.

The quiz reflections helped me to really focus on the real problem of what I did not understand.

I believe quiz reflections help to not to make the same mistakes again, like learning from your own mistakes.

Gave me courage to read the book and know what was really being asked in the problem.

Be able to apply better through process when approaching a problem.

Question3: Would you be doing reflections over mistakes in other courses you will be taking in the future even if the instructor does not require it? Or for other things you will be doing in the future? If yes, give examples.

Yes, I will do reflections in math.

Yes, I could see what I did wrong and how to fix that problem. It will also give me new ideas how to do the problem and make me feel better when doing it.

Yes, I will just learn from the mistakes I made so that I won't make those mistakes again.

Yes, because reflecting back on your work is a must. If you don't face your problems and leave it unsolved, then it will remain mystery till you go back and solve it.

Yes, because it helped me prepare for future exams and also gave me courage to do more problems and get a better understanding of it.

Yes, quiz reflection gives students a second chance to improve grades also we can learn from what we did wrong rather stay confused.

Definitely because it helped me a lot; win win situation; great idea, very helpful and encouraging.

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