Catherine Crockett

TITLE: A Different Approach

ABSTRACT

This paper discusses an approach used to encourage science majors to rethink their attitudes and study habits in a first semester calculus course. Two activities were used to enhance study habits. They are outlining concepts and in-class quizzes designed for self-evaluation of skills. After using both methods in two sections of the calculus course, the students were surveyed to determine if these activities were successful. A majority of the students felt the activities were helpful and wanted to continue them.

INTRODUCTION

Recently, I taught two sections of a course called "Math 144: Calculus with Applications" at a small, liberal arts university. The goal of the course is to develop a conceptual understanding of topics in first semester calculus and their applications. Most of the students who enroll in this course are science majors. While I have taught a variety of levels of calculus, this was my first time teaching calculus filled with science majors. I was looking forward to working with this particular type of student. Unfortunately, after grading the first exam it was clear that these motivated students were having trouble learning the material. The purpose of this paper is to share the activities I used and the student response to these activities.

The majority of students who enroll in Math 144 are freshmen on the Pre-Med track (i.e. Double biology and chemistry majors). Most students take this course in the second semester of their first year of college. The usual class size for a section is between 30 to 35 students. Since 2001, 90% of our students who applied to medical, dental or veterinarian schools have been accepted. These students are familiar with academic success and are highly motivated to earn top grades. However, the students' mathematical backgrounds often vary greatly and some suffer from math anxiety.

During the first five weeks of the semester the students maintained high attendance rates, took notes, answered questions and flourished in group discussions. On the surface, the two classes looked like groups of engaged, successful students. Unfortunately, the first exam revealed a different picture. The scores for the first exam in both classes were bimodal. I asked the students to answer a few background questions. It became clear that there were three different groups of students: students who had a working knowledge of calculus, students exposed to calculus but did not possess a working knowledge and some students who have never taken calculus in their academic career.

Further investigation revealed that the students were studying by memorizing examples and facts exactly as they were written in the text. For some students, they could not recognize different question types. While it is common for freshman to experience lower grades than they may be accustomed to, I took their concern into consideration. At the time, I was reading several articles / reports on STEM education and talking with colleagues in the STEM disciplines.

MOTIVATION

Why should we be concerned with how science majors learn calculus?

We should be concerned about how science majors learn calculus for the sake of both areas: the sciences and mathematics. First semester calculus is often the only mathematics course (besides statistics) that these students are required to take. By helping these students be more successful in calculus, they may be encouraged to take more mathematics. More mathematics for these students sets them up for more success in their careers. In an article titled *Challenges, Connections, and Complexities: Educating for Collaboration* (Jungck, 2005), the author maintains that biology students who learn more math and computer science are often more successful than their peers who learned less math. Another article, *The "Gift" of Mathematics in the Era of Biology* (Steen, 2005), takes this a step further and suggests science research is hindered when the researchers are missing mathematical skills.

Recommendations for closer alliance between mathematics and the sciences have come from several different sources. One such source is the *BIO 2010* report published by the National Academy of Science (Committe on Undergraduate Biology Education to Prepare Research Scienctis for the 21 st Century, 2003). This report is a study on the needed reform in undergraduate education in the life sciences. It states that the "connections between the biological sciences and the physical sciences, mathematics, and computer science are rapidly becoming deeper and more extensive". The first two recommendations for change from this report is the need for more mathematics and critical thinking skills in the life-science course.

Another publication addressing the needs and connections in mathematics and biology is *Math and Bio 2010: Linking Undergraduate Disciplines*. This research was a joint project of the Mathematical Association of America (MAA), the American Association for the Advancement of Science and the American Society for Microbiology. The project addresses and discusses the need for developing quantitative skills in science majors since the life sciences are becoming more quantitative. If we can help these students find success in calculus- it pays off for everyone.

After reading these reports, I wondered if the approach to studying science different than the approach for studying mathematics? I believe the current answer is yes. I interviewed a colleague whose research is in mathematics and science education. Our conversation focused on study methods and attitudes of science majors. She commented that memorization can be an effective study tool in life science courses since there are many facts and vocabulary the students need to learn. However, she cautions that it is not always the best model for learning (Maskiewicz, 2011). In calculus, the emphasis is on the concepts and the application of these concepts. Since most life-science courses have to cover large amounts of facts and concepts, application of these concepts often doesn't occur. For example, in *Connecting Biology and Mathematics: First Prepare the Teachers* (Sorgo, Fall 2010), the author remarks "...science courses rarely develop the skills associated with approaching novel or unfamiliar problems…".

APPROACH- How to help students learn calculus?

There are many resources on undergraduate education in mathematics. I found several articles in various journals discussing different study techniques. For example, in Primus, I found an article titled *Teaching calculus students how to study* (Boelkins, M.R. and Pfaff, T.J., 1998). The authors describe their success in giving the students a daily homework and study plan. However, I felt before introducing any study techniques to my students, it was important to address the students' approach. So the question became, "How do I encourage my students to have a different approach to learning mathematics?"

A colleague of mine referred me to Carol Dweck's research on the effects of beliefs about intelligence and "Achievement goal theory" (Elliott, E.S. and Dweck, C.S., 1988) (Mangels, J.A, Butterfield, B., Lamb J., Good, C.D. and Dweck, C.S., 2006). Dweck's research suggests if students have performance goals instead of learning goals, they are more focused on the validation of ability (i.e. grades). According to Dweck, students with performance goals are more prone to see a new problem or challenge as a threat rather than an opportunity to learn. In contrast, students with learning goals tend to view new problems or challenges as opportunities to learn and grow.

After the first exam was graded and returned, the following was displayed on a screen for the class to read and discuss.

> Research by Carol Dweck
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> Students for whom performance is paramount want to look smart even if it means not learning a thing in the process. For them, each task is a challenge to their self-image, and each setback becomes a personal threat. So they pursue only activities at which they're sure to shine---and avoid the sorts of experiences necessary to grow and flourish in any endeavor. Students with learning goals, on the other hand, take necessary risks and don't worry about failure because each mistake becomes a chance to learn.
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> Dweck's next question: what makes students focus on different goals in the first place? People with performance goals, she reasoned, think intelligence is fixed from birth. People with learning goals have a growth mind-set about intelligence, believing it can be developed. "Study skills and learning skills are inert until they're powered by an active ingredient," Dweck explains. Students may know how to study, but won't want to if they believe their efforts are futile. "If you target that belief, you can see more benefit than you have any reason to hope for."

After reading the screen, the students were given time to think and respond. The students were asked to discuss their opinions and thoughts on the following questions:

1. Are you taking this class to get a good grade only or to get a good grade and learn some calculus?

2. Do you like to work on challenging problems? Why or why not?

3. When you do homework, do you first learn the concept and then work on the assigned homework problems or just go straight to the problems?

4. Do you believe intelligence is fixed at birth? If it is not fixed at birth, what can you do to increase your intelligence?

As a class, we discussed Dweck's research on goals and beliefs and their effects on our actions. Several of the students were willing to be transparent and expressed concerns such as: grades overshadowing learning, not having the freedom to fail and having a great deal of value placed on the perception of being smart. While not all of these issues could be addressed, the main goal was to get them thinking about their philosophy of learning and how it shapes their actions.

To encourage the students to have learning goals, two simple activities were incorporated into the class: outlining a concept together and self-evaluation quizzes. Before doing these activities, I explained to the classes why we were doing these activities based on Dweck's research. The new class routine became outlining concepts once early in the week and taking one non-credit quiz at the end of the week. Both activities were designed to take approximately 10 minutes of class time.

Outlining Concepts:

After asking the students how they studied, it was clear many of them were trying to memorize theorems and examples not written in their own words. Most of the students were using 3 by 5 note cards to help them study for their science courses. Since the students were already using the note cards, I decided to use them for outlining. Each student was given a 3 by 5 note card and put into a group with three other students. The students were asked to work together to identify the key pieces of information required for the specified topic. Next, each student had to determine how to place the information on the note card. I encouraged the students to write the information in a format that suited their own learning style.

Here is an example:

"What are the key points for finding the local minimum or maximum of a function? How could you express this information visually?"

For most students, the picture they drew was "the top of a hill" for the maximum and "bottom of a valley" for the minimum. They described how to find the local extrema in terms of "uphill" and "downhill". This led to a discussion on how to find the extrema when we don't know the graph of the function. We were able to discuss techniques for locating the local minimum and maximum in terms of the first derivative and how the students' pictures were illustrating the behavior of the first derivative.

Another example of a concept we outlined was optimization. Most of the students wrote out a check list of items to complete. While I wasn't too sure about the checklist idea, it turned out that the students themselves determine (correctly) the needed steps to solve these problems. In the end, they were able to put the concepts together to work out the process.

The first time we outlined in class, I started the conversation and did an example of a note card with input from a student on the overhead projector. Within a few weeks, the students were the ones discussing key points and putting their examples on the overhead projector without needing any input from me. One of the unexpected benefits of this activity was the stronger students became more engaged in the class.

Self-Evaluation Quizzes:

Once a week, each class was given a self-evaluation quiz. These were "volunteer" quizzes since the grades were not recorded. The goal was to give students an opportunity to test their knowledge at no risk to their grade. Most of the quizzes asked basic questions. Each quiz covered a topic that was taught earlier in the week. The quiz had two parts; first, write an explanation on how to solve the problem and second, use math to solve the problem. I wanted the students get into the habit of evaluating their level of knowledge on a concept. By having the two steps, the students could identify where they needed to study more. After the class went over the solution, the students were given a list of examples/problems on the same topic for their own practice.

Example:

Question: Suppose you are asked to find the local minimums and maximums of

$$f(x) = x^3 + 5x^2 - 36x\ .$$

Part 1: Write out the steps you would need to do to solve this problem.

Part 2: Using mathematical tools discussed in this class, find the local minimum and maximum of the function.

RESULTS:

Anonymous Surveys

Since this was an experiment, I wanted feedback from the students. I wanted to know if the activities were beneficial and should be continued. A short anonymous survey was passed out to each class after the second exam was taken, but before it was graded and returned. The survey consisted of five questions with space for comments. The first two questions asked the students to rate their opinion on a scale of 1 (strong negative) to 4 (strong affirmative). The next three questions where “Yes” or “No” questions about if they wanted to continue these actives. Then there was a space for comments.

Survey questions:

1. The note cards we wrote in class helped with the material.
2. The quizzes we took in class helped.
3. I would like more quizzes (they don't affect your grade).
4. I felt more prepared for Exam #2 than I did for Exam #1.
5. I would like more note cards.

Summary of the responses:

Out of a total of 58 surveys, 24 of the students said the note cards helped them very much and 23 of the students said the note cards help some (totaling 81.03 % of the students). For question 2, did the quizzes help, 35 students said it helped a lot and 15 said it helped some (totaling 86.2% of the students). 93.1% of the students said "Yes" they would like more quizzes. 82.75% said they felt more prepared for the second exam. 81.03% said they would like more note cards.

Trends:

While this survey is quite limited, the results do indicate that the students want help in learning how to study. Almost all comments written on the survey were positive such as "The note cards are helpful", "Thank you", and "Worked great". One student came to my office to declare she finally believed that she "NOT MATH STUPID”. The one negative comment received was about the note cards and it was "I lose them".

The scores for the second exam were significantly higher and no longer bimodal for both sections. However, the most important change was the increase in the student's confidence level. There was a change in the type of questions being asked during my office hours. Students were coming in asking about specific questions and examples, often citing where they thought they were missing some information. For example, when solving an optimization problem, I had fewer general questions on the set up of the problem and more questions about what to do with a solution not in the feasible domain. The students were thinking and not afraid to suggest ideas.

CONCLUSION

Based on this experience and data, these activities are beneficial to the students. In the future, I would like to continue these activities with a few modifications. I think giving the students more time to digest the material and post/ discuss their thoughts on Dweck's research could be transformative for them. For the quizzes, I would like to try a new format. The students would first take the quiz and then correct the quiz with a peer. Peer feedback could be more effective than going over the solution as a whole class. The success my students found in self-evaluation quizzes and outlining concepts encourages me to continue these efforts in future classes.

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