

MULTIVARIATE CALCULUS STUDENT PERCEPTIONS: HOMEWORK, QUIZZES, AND MOTIVATION

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In this study, six former Multivariate Calculus students were interviewed about their perceptions of the role that an instructor's homework and quiz policies have in motivating them to come to class prepared. Findings indicate that students appreciate the flexibility to select study habits that fit their own learning styles and goals, but that most feel it is important for their instructor to provide some incentive to help them keep on track. Regular careful grading of homework is discouraged, as it places heavy time demands on both students and instructors. Weekly or twice-weekly homework quizzes provide sufficient incentive motivation for Multivariate Calculus students by encouraging timely homework completion without eliciting student perceptions of inefficiency.

What does it take to motivate students to stay on track in their mathematics courses? Learning mathematics requires practice, and practicing mathematics typically means doing homework. Yet even when students have sufficient time available to study mathematics, they often choose not to do so (Cerrito & Levi, 1999). As a result, the question for college mathematics instructors seems to be one of motivation. Small and Gluck define motivation as "a measure of the degree to which a person would expend effort to perform or learn" (Small & Gluck, 1994, as cited in Miller, 2000, p. 14). Some students possess an internal source of motivation, while others need external incentive before they will invest sufficient time in their courses (Kariuki & Wilson, 2002). College students have had countless educational experiences to help them develop and understand their own unique learning styles. When it comes to their own motivation, the students are the experts. Therefore I recruited six of my former Multivariate Calculus students—I'll call them Alex, Ben, Frank, Kevin, Ralph, and Sue—in an effort to better understand how an instructor's quiz and homework policies influence students' study habits.

This qualitative study addresses the following research questions: (1) Do Multivariate Calculus students feel that regular in-class quizzes provide either necessary or sufficient motivation for them to carefully complete their assigned work? (2) Do Multivariate Calculus students feel their mathematics homework is

worthwhile? and (3) What role do regular in-class quizzes play in motivating Multivariate Calculus students to come to class prepared?

Before I began work on the present study, I conducted a simple causal-comparative study to investigate how my own students' homework quality would change as I varied my quiz styles over the span of one semester. I used twice-weekly homework-based quizzes during the semester, and I varied whether students were allowed to use notes and homework to complete the quizzes. I also varied whether the quizzes consisted of identical copies of recent homework questions or contained problems that were merely similar to recent homework questions. Interestingly, I found no significant changes in homework quality across the treatment conditions. For the present study, I hoped to shed light on the subject by conducting a limited number of student interviews to assess students' perceptions of the relationship between quizzes, homework, and motivation.

RELEVANT LITERATURE

Quizzes serve two main purposes in collegiate math classrooms. First, many instructors view quizzes as the preferred way to keep students up-to-date with their coursework. That is the role that the present study seeks to corroborate. Miller (2000) reviewed motivational literature for her dissertation and reported that student motivation is enhanced when classroom structures support students' task-related efforts:

here, regular quizzes support students' homework completion efforts. Second, quizzes open the lines of communication between the instructor and the students. Students' work samples give the instructor a snapshot of student knowledge, skills, and misconceptions, while instructor's comments and corrections highlight areas where students may need to improve. The role of feedback in helping students grow is important, and I routinely make task-related comments as I grade students' work. This is significant because research shows that clear task-related feedback is intrinsically motivating (Brookhart, 1997). As Kevin said in his interview, "If I'm not staying up on the homework, I'm not benefiting from that feedback."

There are drawbacks to using quizzes as well. They take up valuable instructional time, and many students experience anxiety prior to and during the administration of quizzes. Ben explained in his interview: "It's just the fact that it weighs big on your grade, and it makes you nervous." The negative effects of test anxiety on performance are well documented (Crooks, 1988). Moreover, it is unclear exactly how quizzes influence student motivation to come to class prepared. When quizzes provide a source of feedback that can be used to improve future performance, they are likely to increase students' intrinsic motivation. If, on the other hand, quizzes are perceived only as a means of extrinsic motivation for controlling study habits, they are likely to diminish students' overall effort (Brookhart, 1997). Crooks (1988) reported that there is "widespread agreement among reviewers that the extrinsic motivation is problematic" (p. 463). He continues:

Evaluation can be used as a bludgeon to make students learn, and in the short term this may produce significant learning, but the longer term consequences of such an approach appear to be most undesirable, especially for less able students (p. 464).

Therefore, it is important that quizzes be perceived as sources of useful feedback that helps empower students to succeed on future evaluations.

Few studies have asked individual students to discuss their own beliefs about study habits and

motivation (Warton, 2001). Cerrito and Levi (1999) combined quantitative and qualitative methods to examine motivating factors for precalculus mathematics students. Students reported studying more for their math classes than for other classes, and many felt it would be unreasonable to be asked to study more. In addition, Cerrito and Levi found regular collection and grading of homework to be "highly correlated with increased study time in mathematics" (p. 584). Other results show that homework completion rates (as opposed to the sheer quantity of homework assigned) are positively correlated with achievement, and this effect increases with age (Cooper, Lindsay, Nye, & Greathouse, 1998).

Many students fail to prepare adequately for class in the absence of a form of periodic assessment (McDougall & Cordeiro, 1993), and the frequency of testing is positively correlated with both duration and consistency of time devoted to study (Mawhinney, Bostow, Laws, Blumenfeld, & Hopkins, 1971). When the study habits of psychology students were compared under conditions of daily, weekly, and three-week testing schedules, study time was found to be more evenly distributed across the semester when tests were given daily. Weekly and three-week testing schedules, on the other hand, were associated with progressively greater rates of absenteeism during study sessions and with reduced study time until shortly before the test dates. These results "seriously question the effectiveness of large-interval testing schedules as being adequate devices for producing consistent student study behavior" (Mawhinney et al., 1971, p. 263), which suggests that the use of frequent quizzes may help students maintain more effective study habits.

The motivational effectiveness of quizzes may also depend on the students' ability. Greater achievement has been demonstrated among low-GPA students who were given regular in-class quizzes as compared with low-incentive metacognitive homework tasks; high-GPA students showed no group differences (Tuckman, 1994). Without regular quizzes, students spend their time "working on their 'tougher' and 'more demanding' courses" (Tuckman, 1994, p. 11). Many students require a form of external

motivation before they are willing to invest significant time in their course work (Mawhinney et al., 1971).

Because the present study is focused on students involved in an engineering program, the findings by Milligan and Reid (1973) are particularly relevant. Their comparison of students from two sections of a junior-level Mechanical Engineering course showed no significant end-of-semester differences between those students in a highly motivated homework situation in which homework was regularly collected and graded and those in a control group where no such incentive was provided. At first glance, this evidence appears to conflict with Tuckman's (1994) findings regarding the benefits of regular quizzes among low-GPA students. A possible explanation is that students who choose an engineering profession are cut from the same cloth as Tuckman's high-GPA students: perhaps they do not require a form of incentive motivation to study effectively. To address the possible confounds of GPA on the interaction between incentive and motivation, it is important to consider students' GPA when planning research of this sort.

METHOD

Researcher Positionality

In my journey towards a doctorate in mathematics education I have taken several opportunities to "sit in" on math classes, joining the class as an interested spectator without the time-consuming homework expectations. Without regularly completing the assigned homework, the depth of my learning was shallow. I have heard it said that becoming good at mathematics is like becoming good at golf—whatever natural talents you might have been born with, you'll never make par just by watching someone else do it on TV. As I entered this research, I wondered whether my students felt the same way about the role of their own homework.

In many ways, my role as interviewer conflicted with my role as these students' former (or, in one case, current) instructor. As their instructor, I had had the authority to establish the very homework and quiz policies I was asking them to discuss, and as such I had a stake in their answers. I attempted to overcome this potentially

intimidating situation in two ways. First, I made it clear at the beginning of each interview that I was interested in the participant's story, that he or she was the expert, that there were no right answers, and that I was not seeking to validate anything I had done. Second, I tried to use interview questions that directed the participants away from referring to my own classroom policies. Even my second and third interview questions, which were directly related to our shared classroom experiences, were cloaked in the context of an experimental setting that contrasted the two quiz styles; as such, they were open to critique by their very design. The participants also knew of my interest in educational research—they were the subjects of my previous quantitative study on homework quality, and I debriefed the class after that study was complete. As such, I think they were able to look beyond my role as their teacher to view me as a researcher seeking to understand their beliefs about the motivational aspects of their instructors' homework and quiz policies.

Participants

Thirty-seven students completed my fall section of Multivariate Calculus at a western land grant institution; my six participants were among them. All were traditional students, meaning they had entered college immediately following their graduation from high school and were making good progress towards a degree. Most students who enroll in Multivariate Calculus do so en route to a degree in engineering; the rest typically major in mathematics, mathematics education, or computer science. Historically, these have been male-dominated fields, and the population of students in Multivariate Calculus classes typically reflects that fact. The prerequisite for Multivariate Calculus is a passing grade in second-semester Calculus.

I began recruiting participants during the middle of the spring semester. I informed each student of the purpose of my study as well as the expected duration and content of the interview before they agreed to participate. My purposeful sample was designed to select students with a broad range of backgrounds and academic ability levels. Alex, studying electrical engineering, earned a "B" in my class. Ben, studying civil

engineering technology, earned a “D+”. Frank, studying computer engineering, earned an “A”. Kevin, studying mathematics education, earned a “D+”. Ralph, studying civil engineering, earned a “B”. Sue, studying mechanical engineering, earned a “C+”.

Data Collection and Analysis

I used an eight-item semistructured interview script (see Appendix) to guide each interview. The six interviews were held in private conference rooms with the doors closed and lasted 25, 30, 40, 45, 45, and 55 minutes, respectively. I transcribed each interview later the same day or, in one instance, the following morning. Next, I transferred blocks of text (intact sentences or short paragraphs) from my word processor into individual cells in a spreadsheet. I labeled each block of text with the name of the participant and a line number.

As I copied the blocks of text, I performed a preliminary coding of the data based on key ideas. It is best to characterize these preliminary codes, which developed as I selected blocks of text, as keywords. Some blocks of text were given two keywords, and others were not coded at all. I created a glossary of the keywords in a separate spreadsheet. Some examples of the 34 initial keywords I identified are Incentive, Keep Up, More Homework, Less Homework, Forced, Solutions Manual, Skipping Questions, and Grades. As I transferred the blocks of text, I formatted interesting blocks in bold print for easy reference later.

After I had transferred the entire contents of the transcriptions into discrete blocks in the spreadsheet, I reviewed the table of preliminary codes and collapsed them into a collection of major codes and sub codes. I set out to recode the data. With a few more modifications, I finally settled on a set of codes. By using the sorting mechanism built into the spreadsheet program, I was able to sort the data alphabetically by code, sub code, and participant, and then quickly return the data to its original order so I could view each text block in its original context. By sorting the data I was able to detect themes, and by returning the data to its original order I was able to validate

the themes and select relevant quotes to illustrate the themes.

RESULTS

The Role of Quizzes

The most salient theme of the interviews was that, for the majority of these students, quizzes serve as the driving force behind their class preparation. This supports the position that quizzes serve as a necessary form of incentive motivation that keeps students on top of their homework (Mawhinney et al., 1971; Tuckman, 1994). Kevin admitted, “if we didn’t have quizzes every two days, I would probably not do the homework regularly.” Ben thought that he would probably do less homework if there were no quizzes. Why? “Because you know that the quizzes are important for your grade so you try harder and you try to learn it a little better for the quiz.” Alex thought so too, noting that he “wouldn’t feel too bad” about skipping over difficult problems if he knew there would not be a quiz the next day. Ralph thought quizzes gave him the incentive he needed to keep up with everything and avoid falling behind, a point that Kevin echoed with a nervous laugh: “If we had a quiz every Friday, I would probably do all the homework Thursday.” These comments mirror the results demonstrated by Mawhinney et al. (1971) regarding the effects of testing frequency on study habits.

Frank was the notable outlier of my quantitative study on homework quality who surprised me by turning in many more homework problems than I had assigned. He told me that the driving force behind his study habits was simply his overall focus on learning, no matter what subject he is studying. “I usually do as many [problems] as I need to feel comfortable,” he told me. “I enjoy doing it, so I just keep doing it.” Such comments reflect an attitude of intrinsic motivation (Crooks, 1988). Students who are intrinsically motivated tend to view learning as an end in itself. It is therefore somewhat surprising that Frank thinks we need quizzes. “Maybe not twice a week, but at least once a week. It keeps everyone up on the homework,” he said. Why not twice per week? “Because sometimes [quizzes twice a week] can affect your grade because you

don't have time to do the homework every night." To Frank, quizzes are acceptable as long as they don't hurt his grade. When I asked Frank whether he thought quizzes gave him important feedback, he said he thought so, in that feedback was important to "get a feel for how the instructor wants you to show your work... so you don't get docked for certain mathematical errors." Frank's comments reflect the importance of providing task-specific feedback on assessments and of establishing clear criteria so students know what they will be held accountable for (Crooks, 1988; Natriello, 1987).

Surprisingly, the strongest arguments against the necessity of quizzes came from my quietest participant. Sue thought quizzes have the same effect as regular homework collection—they both serve to keep students caught up with the homework—but she didn't sound convinced that doing the homework was particularly important. Sue told me that she learns best by sitting somewhere on campus, preferably with some of her classmates, just "looking over the book and looking at the homework problems." Like the students in Cerrito and Levi's (1999) study, Sue thinks too much time is expected on homework. "I think it's because I learn better by looking over problems rather than sitting down and doing them." She admitted, "I didn't do the homework every single time." After all, she shrugged, "it wasn't really worth points." While Sue admitted that having two quizzes per week did motivate her to keep up (a point she seasoned with a bit of nervous laughter), it was apparent that she viewed the role of quizzes somewhat differently. Quizzes gave her something to "look over" at exam time, and they gave her a glimpse into the mind of her instructor. The benefits of quizzes were "to see how you graded," she told me, and "to see what steps I went wrong on and how to fix it." Here again we see evidence of the importance of task-specific feedback in defining the motivational characteristics of assessments (Crooks, 1988; Natriello, 1987).

Is Homework Really Worthwhile?

The participants agreed that homework plays an important role in learning. Ralph likened homework to a lab experience in science class, "where you practice it and you understand how

different things work." Kevin viewed it as a buffer that stands between his developing knowledge and the instructor's critical eye. Ben told me homework gives students practice at what they need to know, and thought, "If you know how to do the homework, then you should know how to do the quizzes." Sue even admitted that it might have been beneficial for me to have collected her homework, although "I wouldn't have liked it as much," she joked. In fact, Sue does lots of homework for classes related to her major. Math homework just tends to get redundant, she said. Sue's comment is in line with some researchers' concerns that the cumulative effects of consistently long homework assignments might eventually diminish the intrinsic value associated with doing homework (Cooper et al., 1998). Alex, however, nearly dismissed the question when I asked him what the role of homework should be: "obviously, to learn the material." Hardworking Frank's view was that homework should just help students become comfortable with the concepts they are trying to learn and to let them know whether they need to do more problems or not. While these students differed on the time and effort they allocated to completing their assignments, each student saw benefits in doing homework.

Ralph hadn't always thought homework was important, however. When he first came to college, he confessed, he thought he could get by without doing his homework. Now he thinks homework is the most important thing to do in preparation for quizzes. Kevin thought so, too. In fact, he mirrored my own experience when he told me, "You can go to every class and attend every lecture and still not do well just because you haven't put your face in the material." Sue didn't seem to be particularly concerned about her math homework. She thought it was nice of the instructor to assign problems, especially if they weren't collected, because it helped her see "what kind of questions are relevant." That way, she knew what to "look over" when preparing for quizzes and exams.

Should Homework be Graded?

The students I interviewed all felt that any benefits of regular homework collection could be achieved just as well by regular in-class quizzes. More importantly, these students expressed mostly

negative feelings towards having their homework graded regularly. Frank, who routinely does more problems than are assigned, did not want to get docked for mistakes he made on his own time. While he thought it might be helpful to rewrite his normally sloppy homework, he wasn't excited about spending the extra time. Ralph shared Frank's sentiments, saying, "My point of doing the homework isn't to do a whole problem and have it look pretty, it was to figure out how to do it." And Kevin, who viewed homework as a buffer and expressed a dislike for being forced to submit unpolished work, pointed out, "Just because you're getting graded daily on every homework assignment, you're not really understanding it." Alex thought the only difference between having quizzes twice a week and having homework regularly "graded to a T" would be that, in the latter case, his homework would have to be really neat and orderly. "But I think as far as learning goes, it's sort of the same effect." And Sue was pleased that I didn't collect her homework because, "It didn't waste my time."

CONCLUSION

Collectively the data suggest that these Multivariate Calculus students recognize the need for a form of external incentive to motivate them to do their homework. Regular grading and collecting of homework forces students to do their homework neatly and completely, but the students I interviewed felt there would be little benefit in doing so. Alex told me that giving regular quizzes has the same effect as collecting and grading homework, and he would prefer to have quizzes instead of graded homework "for the reason that you're still doing the work." These students would agree with Milligan and Reid's (1973) conclusion that collecting, correcting, and grading homework is a waste of resources "unless an effective means can be devised whereby the student capitalizes on this type of feedback" (p. 33).

Also in support of Milligan and Reid's (1973) findings, the students I interviewed recognize that homework is important for learning. However, they appreciate the flexibility to choose how and to what extent they do their homework and prepare for class. Sue's method of "looking

over the homework" was enough to earn her a C+ in the course. Frank did many more problems than were assigned and was glad he was not marked down for mistakes he might have made on those problems. The students affirm that their instructor's policies play a role in helping to motivate them to meet their own standards of success.

Students' goals and the incentives they require to meet them are in a state of change. Consider Ralph's account of his early college days:

I didn't do too well in those classes. And that was because I was having too much fun and screwing around. Not doing my homework and thinking that, you know, 'Oh yeah, I get it from class,' and [only later] figuring out that 'Yeah this homework's really necessary.' The [frequent] quizzes like you had might have done it, but even then that might even be saying too much, giving me too much credit. I screwed around too much, and my GPA shows it. I think you can help [as an instructor, with the homework and quiz policies you set]... but maybe at that time in my life it wouldn't have helped.

Today, Ralph works hard to learn the material in his courses. Yet without an external incentive, he openly acknowledges that he would do his homework less frequently. Ralph's comments support Mawhinney et al.'s (1971) conclusion that infrequent assessments promote inconsistent study habits.

How can one select a grading scheme to accommodate the needs of such a diverse population of students? Two important considerations arise from this study. First, we should take care to select policies that do not place excessive burdens on individual students. Most of the Multivariate Calculus students I interviewed realize that homework is necessary for learning, and all saw benefits in doing homework. With sufficient incentive, they will get their work done. For the students I interviewed, twice-weekly homework-based quizzes were appropriate. The second consideration stems from a review of motivation research: assessments that do not provide task-specific feedback have a tendency to undermine student motivation rather than bolster it (Butler & Nisan, 1986; Crooks, 1988; Milligan &

Reid, 1973). I routinely provide task-specific feedback when I grade student work. In light of the research cited above, it is likely that the feedback I provided on these students' quizzes played a role in their perceiving my quizzes as motivational. As the president of the Assessment Training Institute, Inc., warns, "we should not be so naïve as to believe that we can force our students to care merely by manipulating schedules of reinforcement and punishment" (Stiggins, 1999, p. 197). If our assessments are to motivate our students, we must provide meaningful feedback they can use to improve their future performances.

Further research is needed to discover appropriate baseline levels of incentive for a broader variety of students. Homework-based quizzes provided sufficient incentive for the Multivariate Calculus students I interviewed, who perceive little added benefit to having all of their homework graded. Can the same be said of Introductory Statistics students, Precalculus students, Elementary Education students, and others? I recently asked for a show of hands from a class of Language of Mathematics students, whose homework I collected and graded daily at the recommendation of the course supervisor. After I shared the results of the present study, I asked the students whether they thought it was important that I continue to collect their homework every day. I was surprised to see many of them nod in earnest, suggesting that my findings may have been quite different if I had not been working with students from an upper-division calculus class. There is still work to be done before we can fully understand what it takes to enhance motivation of mathematics students at all levels.

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Appendix

Semi-structured Interview Script

1. "Describe how you normally go about doing your homework." Depending on the depth of response, I supplied additional prompts, such as: "What do you do after finishing a problem? Do you ever check your work? How do you use the solutions manual? What if it's correct? What if it's not? Do you often work with other students?"
2. "Remember how my quizzes often were direct copies of homework questions from the previous few class periods? Imagine you are preparing for a quiz like that, one that will be given at the beginning of the next class period. In what ways would that affect how you go about doing your homework?"
3. "For a while, I allowed you to use your homework and class notes on the quizzes, but the questions were not identical to homework problems you'd seen; how did that influence your study habits?"
4. "Should homework be graded regularly? Why or why not? Are there any drawbacks?"
5. "What do you think the role of homework should be in math class?"
6. "What do you think the role of quizzes should be in math class?"
7. "You've been a student for many years now (since you were five years old). Have you had any instructors who had unique homework / quiz policies that were either helpful or hurtful? What were they?"
8. "What other factors do you think influence your performance and motivation in a math class?"