Two-part testing

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In any mathematics course, the mastery of a concept is far deeper than just manipulating symbols, sketching curves, or approximating solutions. In fact, “reform” calculus elucidates this in its “rule of three,” the graphical, numerical, and symbolic perspectives. Technology aids students to approach concepts in single-variable calculus from all three perspectives. For example, a graphing calculator or a computer algebra system (CAS) accurately plots the graph of a function so that a student may immediately identify many of the function’s properties with little effort. But technology presents new challenges. Specifically, how do we, as instructors, differentiate a student’s grasp of mathematics from her computational agility? Does use of technology in student assessment favor a student with a faster computer or a better calculator? How do we “test with technology” when computer access in the classrooms is inadequate and testing in our computer labs is infeasible?

These queries arose in a discussion with my colleague, Eliza Berry, of California State University, Chico. We both desired to use technology in our assessments yet we both agreed that the primary goal of student assessment should be to understand the student’s conceptual grasp of the material. We have found testing in two parts to be effective tool toward achieving a balance between these two ideals. For our first-year calculus courses, we have developed a two-part testing format consisting of a take-home portion to emphasize the use of technology to solve challenging problems, and an in-class portion to emphasize basic grasp of the underlying concepts and “paper-and-pencil” skills. The take-home portion may contain multi-step problems, calculationally intensive problems, or problems where graphs are helpful. We assign the take-home portion as collaborative work, completed in groups of three to four students each. The in-class portion may contain conceptual questions prompting free responses, questions to assess particular problem-solving skills, or questions about definitions and theorems. No computers or calculators are permitted on the in-class portion. The in-class portion typically is weighed twice as heavily as the take-home portion. (To compare the weights to those of a similar assessment scheme, see Nancy Hagelgans in Assessment Practices in Undergraduate Mathematics, Bonnie Gold, et al., eds., MAA Notes 49 (1999), pp. 134-6.)

Some of the outcomes of two-part testing in calculus were unsurprising. If the content of the two parts overlapped (initially, we made them so, assigning the take-home portion a week before the in-class portion, setting the due date as the day of the in-class portion), the students began studying for their in-class exams sooner and in general were better prepared for their in-class exams. Their mathematical writing skills improved over the course of the term, generally exhibiting clearer exposition and a better balance of prose and symbols. Their ability to read mathematics and to solve problems independently also
improved with time. Finally, students developed decision-making skills about the appropriate use of technology, customizing use of technology to the tasks at hand as well as to their own levels of comfort with technology.

But two-part testing also yielded some surprises. We were initially concerned about the degree of difficulty of the take-home exam questions. To our surprise, the students did not rebel against being given harder problems (especially when their peers in other sections of calculus were given more traditional exams). In subsequent semesters I have been able to increase the depth of the questions and to use the take-home exam to step them through a topic that was not covered in class, such as the Newton-Raphson method of approximating roots or the behavior of the solutions to a logistic differential equation. Still the students responded well. Another unexpected result was the increased student/faculty engagement in dialogue both in class and in our offices. Students have been eager to explain their work, and their retention and verbal communication skills both improved as a result. I was delighted to see my students come to me as a group to explain their progress on the problem and their difficulties. This sense of teamwork also reduced our concerns about cheating, as the groups communicated regularly among members, but not with other groups. The biggest surprise, though, was that grading didn’t take as long as expected. Despite having two sets of papers to grade for each exam, grading time remains roughly the same, some due to the collaborative nature of the take-home portion, and some to stronger student performance overall.

I have continued to implement two-part testing in undergraduate mathematics courses at a variety of levels. I have experimented with the timing and the frequency of the take-home portions, sometimes staggering the two parts or giving more take-home exams or fewer. In an upper division geometry course, I even assigned a semester-long collaborative project in which the students were free to use a CAS or Geometer’s Sketchpad as part of their project.

Anecdotal evidence indicates that two-part testing has benefits exceeding our initial goal of separating computational skills from conceptual understanding. It seems that student motivation and engagement have increased at all ability levels. Students are even able to use the take-home exams to teach themselves new concepts. I have observed better retention throughout the semester, perhaps because concepts are tested in more than one paradigm. I have not conducted any formal study into the impact of two-part testing. Indeed, I would hope that at the 2002 Roundtable I could learn more about developing specific tools to measure the effectiveness of this new assessment paradigm.