How Do We Evaluate Student Understanding?

Karen Rhea
Introductory Program Director
Mathematics

krhea@umich.edu  Dean’s Symposium, May 2009

Calculus at Michigan:
• Multiple sections
• Each class meets 3 times a week for 80 minutes each session
• Classrooms have square tables, each designed for 4 students
• Instructors are expected to teach in an “interactive” style

Grading
• All exams (two midterms and final) are uniform – set by the course coordinators
• No instructor grades their own section
• Exams are designed to test problem-solving and “understanding”—data is available on each problem
• Manipulations and skills are tested on proctored “gateway” tests

Struggling with how to evaluate our program
-- new chairman
-- external review
-- regular (i.e, repeated) pressure from the Dean and, in a sense, other departments
-- plus, we really do care....

Calculus Concept Inventory (CCI)
• Developed by an expert panel, including psychometric analysis, with NSF funding,
• Modeled after the Force Concept Inventory (FCI) in Physics —also spread to other areas of Physics, Biology, Chemistry, Statistics
• Tests only concepts—not computational skills — 22 Multi-choice questions
• Based on normalized gain, defined (for a class) as

\[ g = \frac{\mu_f - \mu_0}{100 - \mu_0} \]

• Fall ‘08 we administered the test to all Calculus I sections
• Administered in a proctored lab
  --pre-test during first week
  --post-test during last week
• Students had one attempt, 30 minutes, timed for both pre- and post-tests
• None of the instructors saw (or have seen) the test
**Ramifications**
- Large numbers of students had to be coaxed into the lab during two short windows of time
- Students wanted to know how to “prepare” – told them not to
- Instructors wanted to know how to prepare students – told them not to

**Incentives**
- Pre-test––worth a in-class quiz grade
- Post-test––worth 5 points (5%) of the final exam grade

We have looked at date/time stamps, and there appears to be no evidence that students were “blowing off” the first test.)

95.5% of the students who took the pre-test also took the post-test

**Results**
- Average “gain” over 51 sections was 0.35
- 10 sections had a gain of 0.40 to 0.44
- 7 sections gained 0.24–0.29
- The one section below 0.24 (at 0.21) was a “special” section for “at risk” students smallest section (12 students)

**What does this mean?**
- Of all other sections tested, there were basically three instructors (one at UT–Austin, one in Oregon, and one at U–Maryland) that had “gain” scores of over 0.21
- No other program (thus far) has shown gain across the board
- Many other institutions have administered the test, but not all have submitted data

**Physics results showed IE makes the difference**
- This type of teaching is not “natural” for most instructors
- Students don’t always “appreciate” this type of classroom (may not call it “teaching”)
- I believe it is a very important part of our course

**Other participating schools**
- Cornell University
- Catawba College
- Joliet College
- Macalester College
- Montana Missoula
- NW Missouri
- Occidental College
- Polytechnic University
- St. John Fisher College
- University of Arizona
- Wayne College
- U–T Austin
- U Oregon
- U Illinois
- UIUC
- U Maryland
Next steps…

- NSF proposal to study Calculus nationwide
- 8 schools will be selected (over 600 responded)
- Goals of the study:
  1. To improve our understanding of the demographics of students who enroll in calculus,
  2. To measure the impact of the various characteristics of calculus classes that are believed to influence student success,
  3. To conduct explanatory case study analysis of exemplary programs in order to identify why and how these programs succeed,
  4. To develop a theoretical framework that articulates the factors under which students are likely to succeed in calculus, and
  5. To use the results of these studies and the influence of the MAA to leverage improvements in calculus instruction across the United States.

Interested?

- Contact me at krhea@umich.edu
- Contact Jerry Epstein at jepstein@poly.edu or jerepst@att.net

Jerry can give you some samples of the questions on the CCI exam

Sample CCI-type question:

The derivative of a function is negative everywhere on the interval $x=2$ to $x=3$. Where on this interval does the function have its maximum value?

A.) At $x=2$.
B.) We cannot tell if it has a maximum since we don't know where the second derivative is negative.
C.) Somewhere between $x=2$ and $x=3$.
D.) At $x=3$.
E.) It does not have a maximum, since the derivative is never zero.