How Do We Evaluate Student Understanding?

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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**

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

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

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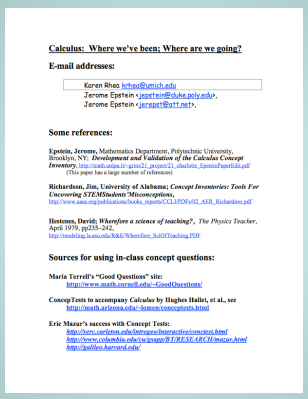
- Contact Jerry Epstein at
  jepstein@poly.edu or jerepst@att.net

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



Calculus: Where we've been; Where are we going?

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Some references:

Epstein, Jerome, Mathematics Department, Polytechnic University, Brooklyn, NY; ***Development and Validation of the Calculus Concept Inventory***, http://math.unipa.it/~grim/21_progno21_charlotte_EpsteinPaperEdit.pdf
(This paper has a large number of references)

Richardson, Jim, University of Alabama; ***Concept Inventories: Tools For Uncovering STEMStudents' Misconceptions,*** http://www.aaas.org/publications/books_reports/CCLI/PDFs/02_AER_Richardson.pdf

Hestenes, David; ***Wherefore a science of teaching?****, The Physics Teacher*, April 1979, pp235–242, http://modeling.la.asu.edu/R&E/Wherefore_SciOfTeaching.PDF

Sources for using in-class concept questions:

Maria Terrell's "Good Questions" site:
http://www.math.cornell.edu/~GoodQuestions/

ConcepTests to accompany *Calculus* by Hughes Hallet, et al., see
http://math.arizona.edu/~lomen/conceptests.html

Eric Mazur's success with Concept Tests:
http://kerr.carleton.edu/homepages/Interactive/concept.html
http://www.columbia.edu/cu/gsapp/BT/RESEARCH/mazur.html
http://galileo.harvard.edu/

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.