Efforts at Rutgers University

Enhancing the Preparation of Mathematics Graduate Students for the Educational Component of Academic Careers.

RUTGERS: THE CONTEXT AND CHALLENGE

Rutgers University, the State University of New Jersey
- chartered as a colonial college in 1766
- won responsibility for New Jersey's land-grant institution in1864
- assumed university status in 1924,
- became the state university in 1956.

Mission: to provide education, research and public service of the highest quality.

Mathematics Department at Rutgers – New Brunswick/Piscataway
- top-20 ranking in the United States.
- over 55 tenured faculty members with regular teaching duties
- decreasing staff of assistant professors, post-docs, lecturers, and adjuncts.
- relatively small graduate program
  - 65 supported graduate students (all pursuing PhD's);
  - no unsupported doctoral students;
  - 8-10 finish each year; three-quarters enter academic careers.
  - very few fail out; most who depart cite changing interests.
- huge undergraduate teaching responsibility

The undergraduate program in mathematicians at Rutgers (like those at most large public universities) serves many students with diverse backgrounds and interests.

Enrollments: **10,000** each fall; **8,000**, each spring; **2,000**, each summer.

Three-quarters of all major programs offered at RU require calculus.

To meet the RU quantitative reasoning requirement, all students must establish basic proficiency in math *and* pass a credit-bearing course in math.

Department offers majors in Mathematics and Biomathematics; a minor in Math, interdisciplinary major in Mathematics and Statistics.

Only 4% of enrollments are mathematics majors in junior or senior status.

OUR CHALLENGE.

Rutgers mathematicians (like most faculty members at research universities) find satisfaction in solving hard problems in their areas of expertise.

- We want our teaching to be effective and satisfying -- for ourselves as well as our students.
- We want to assist our doctoral students to communicate mathematics effectively wherever their careers take them.
- We have **less autonomy in teaching than in research** to choose work appropriate to their own strengths and interests.

Instead we
- have limited control over the preparation of our students;
- have limited influence over students' motivation
- must adjust course content and exit standards in response to partner disciplines

OUR RESPONSES.

Many changes over 15 years -- what we teach and how we teach it.

These changes enhance the preparation of graduate students for academic careers.

OUR STRATEGY

- Initiatives arise from small informal groups.
- Innovations are tried out in small settings under optimal conditions.
- Departmental discussion and approval precede permanent adoption.
- Neither unanimous support nor unanimous participation is required!
- Unexpected opportunities are exploited.
- Successes are communicated in department and outside it; failures are dropped fast.
- Our efforts have won us resources we would not otherwise have had.

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THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

GUIDING PRINCIPLE 1. - Education is a complex enterprise.

Progress is necessarily incremental.

Long-standing hard problems just don't have quick and easy solutions.

Facility in learning and doing mathematics does not ensure communicating mathematical ideas fluently and effectively
It is hard to explain what has always seemed obvious.

Methods that work well in selective institutions (where many faculty members and graduate students have had their own educations) may not be appropriate in other places or for undergraduates with different interests and talents.

Graduates of selective institutions may be unfamiliar with the issues involved in providing mathematical education to future elementary and secondary teachers. This is a crucial part of the undergraduate program in mathematics at many American colleges and universities. And even in American graduate departments, mathematicians prepare future teachers of teachers.

GUIDING PRINCIPLE 2. - People tend to teach as they were taught.

To be effective, a departmental program to prepare future faculty needs credibility with its participants. It is essential that the department display a general commitment to effective education and model a variety of good practices.

Faculty members are often willing to try out suggested innovations that make sense to them and have worked well for their colleagues.

Some innovations reduce total work-load even if they involve added contact time

"Gee, it's more fun to teach when the students learn."

Some Changes in Rutgers courses and methods over the last 15 years

- EXCEL(since 1990): Intensive calculus for properly prepared students from underrepresented groups.
  12 full professors taught the course in its first 4 years: and trained TA's as workshop leaders.

We have seen this experience help our PhD's get jobs.
One has used these methods in a new university in Colombia.

- Workshops, adapting the EXCEL model added to required upper-level courses.
  Help all majors understand and communicate the basic ideas of our discipline (1994).
  Senior faculty lead the workshops and learn to listen to students.
  Graduate students have helped in these workshops, see students learning to "think like math majors."
- Workshops and calculator use was added to calculus courses (1996).
  Based partly on ideas of "calculus reform", and experience in courses for majors.
  Faculty and TA's worked with undergraduate "peer mentors", increasing the vertical integration.
  Especially valuable for international TAs coming from educational systems very different from that in the U.S.
- Courses on current mathematics enhance the "classical" curriculum:
  - o number theory as applied to cryptography (since 1999),
  - o wavelets in image reconstruction (planned for 2004),
  - o mathematical biology (newest in 2001).

  Graduate students assisted in the development and delivery of these new courses.

- Technology (WeBWorK, MAPLE, MATLAB) was added (beginning in early 90's)
  to do what machines do best (calculating and checking routine exercises)
  so humans can attend to what humans need to do (setting up the calculations and interpreting their results),
  "Head TA's" helped others to learn these systems, and helped us debug them.

New educational work for faculty, postdoctoral fellows, and graduate students

- "Rotations" - "early introductions to research" for entering graduate students. Under our VIGRE grant, first- and second-year graduate students worked with a variety of faculty outside formal classroom settings: learning to read research papers, working on accessible pieces of ongoing research, helping with course enhancement projects.
- Research experiences for undergraduates. Teams included undergraduates, graduate students, post-doctoral fellows and/or faculty members. They worked (usually in a summer) on problems where the method of attack was not completely clear and the answer was surely not in the "back of the book".
- Our new honors seminars. Undergraduate students study topics not usually seen in a college course, prepare and present talks on them to fellow students. Senior faculty guide selection of topics; junior faculty and advanced grad students mentor individual students, usually for two or three weeks.
- Problem sessions associated with first-year graduate courses. This activity for VIGRE postdoctoral fellows, under guidance of the course instructors, provided a structured introduction to the challenges of graduate instruction.

Other non-traditional interactions among faculty and students
- Formal orientation for all new faculty members (not just for junior faculty.)
- Formal mentoring for junior colleagues in both teaching and research.
- Coordination of multi-section courses; communal grading of common final exams.
- Pre-service training and in-service mentoring for undergraduate peer mentors who assist during workshops and do routine grading.
- Advice to faculty, post-doc, and grad students who mentor undergraduate research.
- Cooperation with the pre-service and in-service training of tutors for various University-sponsored tutoring operations.

GUIDING PRINCIPLE 3 - Promote serious discourse about education throughout the department. Encourage professional development, require some.

Departmental TA-training program.

- Successful completion required before a TA gets a classroom assignment.
- TA's get grading assignments before completing training.
- Serves graduate students in Mathematics, Statistics, Physics and Operations Research.
- Meets for about 10 weeks during the spring term,
- Is led by a senior faculty member known for good teaching.
- Topics and Activities
  - o Goals and methods of the courses that use TA's
  - o Attending classes of experienced TA's with a variety of assignments,
  - o Structured discussions of visits and a more detailed discussion of duties,
  - o Practice teaching with videotaping; review and critique of videotape
- The TA Trainer also visits each successful TA's class the next fall & offers guidance.
- Professors are asked to meet regularly with their TA's, to visit recitation classes, and to offer continuing guidance.
- Faculty reports on TA's are used in writing "teaching letters" in support of job candidates.

Mathematical Career Seminars in the Department (examples)

Department chairs discussed their expectations and hiring processes.

Recently hired Assistant Professors at a variety of departments discussed balancing teaching, research, and service.

U.S. and international graduate students described undergraduate programs around the world and around our country.

Speakers on non-academic careers:
to help answer student questions like "Will I ever use this math stuff again?"
and "If I won't teach, why must I learn to communicate?"

Pizza Seminar

a graduate student activity with departmental and university funding

Professional development outside Rutgers (for faculty and graduate students)

- *Project NExT* (New Experiences in Teaching, a project of the MAA). www.archives.math.utk.edu/projnext/
  Matching funding for two post-doctoral fellows in our department (Arup Mukherjee, Amelia Taylor).
  Supported the applications of two of our doctoral students (Bernardo Abrego, Silvia Fernandez) for NExT Fellowships.
- *PMET* (Preparing Mathematicians to Educate Teachers) www.maa.org
- *MER Forum* Special Sessions and Workshops. Rapid dissemination and discussion of ideas. www.math.uic.edu/MER/
- *CRUME* (AMS Committee on Research on Undergraduate Mathematics Education) www.ams.org
- *Preparing Future Faculty* www.preparing-faculty.org.

Colloquia and Special Lectures (examples):

Don Lewis (Chair, Mathematics, U. of Michigan; Later head of DMS at NSF). Educational change in his department.

Hyman Bass and Deborah Ball (U. of Michigan). Mathematical understanding teachers need for the middle grades.

The question of finding a mathematically honest but teachable definition of "polygon" gave rise to vigorous disagreement among our faculty. Is the polygon the boundary or the bounded region? If polygons are certain unions of line segments, can a square have positive area?

Lara Alcock (Rutgers, Math and Graduate School of Education). Results of research at the University of Warwick on how undergraduates in abstract algebra and real analysis worked with formal definitions.

William Barker (Bowdoin College). What should go into a college course on geometry? How much Euclid? how to balance axiomatic treatments against more modern treatments? What non-Euclidean geometry?

INNOVATIONS UNDER DEVELOPMENT

Credit-bearing graduate courses to replace TA Training

Teaching Math in College and University I,
- weekly meetings through academic year.
- required of all graduate students with TA support, usually in their first year.
  - o goals of our undergraduate program;
  - o theory and practices of grading at various levels; and an
  - o introduction to Workshop Sessions and Recitation Sessions.
  - o activities of our current TA Training Program in greater depth
  - o constructing quizzes, grading exams, and academic integrity.

Teaching Math in College and University II.
- weekly meetings for a year.
- designed for advanced graduate students focusing on roles of faculty:
  - o structuring courses (syllabus, textbook, exams, grading policy);
  - o course coordination; supervising TA's, mentoring
  - o academic integrity issues (cheating, abuse of authority, abusive students);
  - o design and approval of new courses;
  - o special challenges (prospective teachers, honors, remediation, REU;
  - o service (mentoring, hiring and promotion, letters of recommendation, math clubs, course development)
  - o resources available through professional societies,
  - o research on mathematics education.

"Bridge seminars" for second-year graduate students.
Assist younger graduate students to move from classroom toward research
Broaden teaching experience for senior graduate students and junior faculty
Vertical integration of planning under senior faculty guidance.

Math-Major Lounge and Study Center in central department space.
- o peer study groups focused on three critical courses (Intro. to Math Reasoning, Elem. Real Analysis, Elem. Abstract Algebra.)
- o graduate students facilitating study groups (contingent on funding)
- o site for research on how students think and learn in these courses
- o pre- and in-service training for TA's and peer mentors
- o seminars in teaching issues for students and faculty
  - Discussions of case studies from Sol Friedberg's "Teaching Mathematics in Colleges and Universities"
  - Micro-teaching evenings on the Harvard model.

Optional Internships (some with grant funded stipends):
- o Center for Mathematics in America's Cities NSF grant to RU;
- o NJ Math and Science Partnership NSF grant to RU;
- o research on university-level mathematics education
- o Working with students or teachers in RU outreach activities
- o Working with summer "Math Camps" for talented HS students
- o Working with REU's at RU or elsewhere.
- o Park City Math Institute (vertically integrated summer meetings)
- o Internships in mathematics-related industrial or government activities