

## The REU Experience at Iowa State University

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### 1. Overview

Undergraduate research is a high priority at Iowa State University. The ISU Mathematics Department has hosted summer REUs for seven of the past nine years. In addition, mathematics faculty regularly work with ISU undergraduates on research projects, primarily through the ISU Honors Program. This report covers only the ISU Math REU that took place during the summers 2004-2006, a program which involved research in a wide range of areas, and whose largest source of funding was an NSF REU-site grant. The ISU Math REU was directed by Justin Peters (Mathematics Department Chair) and Leslie Hogben, and was managed by Hogben. It is anticipated that this program will serve as a model for future summer mathematics REUs at ISU.



FIGURE 1. The 2005 REU.

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With up to sixteen undergraduates and a total of about thirty people involved each summer, the ISU Math REU was one of the larger NSF mathematics REU sites and one of the largest undergraduate summer research programs on the ISU campus. The program was specifically designed to exploit the strengths of a large research university (ready access to a large number of faculty and graduate students doing research), while at the same time giving students the kind of individual attention and mentoring that is often found only at smaller colleges. The research topics varied from year to year, depending on which faculty members served as mentors, although projects have been offered every year in dynamical systems, linear algebra, and mathematical biology.

## 2. Research Projects

The research projects were selected by the faculty mentors. During the fall, the mentors for the following summer were identified and general descriptions of the areas to be offered were posted on the ISU Math REU web-site, <http://orion.math.iastate.edu/reu/homepage.html>. The applicants were instructed to identify up to three projects and explain their interest. The mentors and REU directors jointly selected the participants. In late spring the mentors selected the specific research problems, based on their current research and student interests.

A typical research team consisted of two undergraduates, one graduate student and one faculty member; an average of eight projects were offered each summer. Research groups met daily for at least an hour. Initially, faculty taught the necessary background to students; later students reported progress and discussed obstacles. Each project team produced a final paper (typically 20 pages) and presented an hour-long report at the symposium held in the eighth (final) week of the program.



FIGURE 2. The 2006 REU students ask, “What do you call a baby eigensheep?” (A lamb, duh.)

As all mentors are active researchers who publish regularly, it was intended that many of the projects result in papers in professional journals, and this in fact occurred. Since 2004, five ISU Math REU papers have appeared in journals such as *Linear Algebra and Its Applications*, *Journal of Mathematical Analysis and Applications*, and *Mathematical Biosciences and Engineering*. Four additional papers are under review, and several from summer 2006 are in preparation.

Approximately ten students have made research presentations at undergraduate conferences (primarily the Young Mathematicians Conference at Ohio State).

The mathematical diversity of the ISU Math REU can be seen from list of projects and the number of faculty involved. Faculty mentors have supervised the research projects listed below:

- **Leslie Hogben** Matrix theory: Matrix completion problems; Rational realization of eigenvalues of tree sign patterns; Minimum rank of symmetric matrices described by a graph; Matrix  $D$ -stability.
- **Wolfgang Kliemann, Justin Peters, Jiyeon Suh** Dynamical systems: Dynamical systems in projective space; Morse decompositions, attractors and chain recurrence; Dynamical systems and group theory; Mathematics of the heart beat cycle; Dynamically coupled linear ODEs and Markov chains.
- **Khalid Boushaba, Howard Levine, Michael Smiley** Modeling of tumor angiogenesis: Negative feedback systems; Fibroblast growth factor competition; Tumor dormancy; SELEX against multiple targets; Regulation of secondary metastases by plasmin.
- **Roger Alexander** Numerical Analysis: Analysis of software for stiff ODEs; Runge-Kutta Design and Optimization.
- **Sung-Yell Song** Combinatorics and graph theory: Polygonal designs; Strongly regular graphs.
- **Zhijun Wu** Biomolecular modeling: Thermodynamic fluctuations of proteins; Optimizing protein structural alignment.
- **Dan Ashlock** Evolution of hybrid grid robots.
- **Cliff Bergman, Jennifer Davidson** Methods of steganalysis.
- **Jonathan D. H. Smith** Partial semigroups and binomial coefficients to prime square modulus.
- **Eric Weber** Attack on hiding messages in oversampled Fourier coefficients.

### 3. Student Recruiting and Funding

The primary funding source for the ISU Math REU was the NSF REU-site grant DMS 0353880, which supported twelve undergraduates annually; these students were recruited primarily through the ISU Math REU web-site and the NSF REU web-site. As is typical of REUs listed on the NSF web-site, there was no difficulty recruiting far more well-qualified applicants than could be accepted. The students came from all over the country, attending school in more than 20 states. Due to student self-selection and regional recruiting, approximately 45% of the students lived or attended college in Iowa or adjacent states. The students came from a variety of undergraduate institutions, including about 45% from liberal arts colleges.

The ISU Math REU also recruited students through the Alliance for the Production of African American Ph.D.s in the Mathematical Sciences. The Alliance is an NSF-supported partnership between the Iowa Regents universities (Iowa State, University of Iowa, and University of Northern Iowa) and several historically black colleges and universities, including Alabama A&M University, Florida A&M University and Jackson State University. The Alliance has supported up to four participants annually. Due to a miscommunication, the ISU Math REU was not listed on the 2006 Alliance web-site and had no 2006 Alliance participants, but plans have been made to host Alliance students in 2007.

Additional participants have been funded through faculty member grants from various agencies and through the NASA/Pipelines Sciencebound program.

The ISU Math REU had no funding targeted specifically at women, but actively recruited women and collaborated with the ISU Program for Women in Science and Engineering, both in recruitment and to offer additional programming through PWSE to female participants. More than 40% of the undergraduates who participated are female, one third of the graduates students are female, and several female faculty were involved (including one of the directors).

Since the research teams functioned better when students had similar mathematical preparation, the majority of the research teams paired students from the same funding program, but when feasible, teams mixed students across programs.

All ISU Math REU students focused their main efforts on their research projects, and participated in additional common academic activities. All were invited to the social activities, regardless of funding source. However, in practice, students funded by another program were sometimes required to participate in activities for that program and/or housed separately from the students funded by the REU-site grant. This sometimes restricted their involvement with the ISU Math REU.

#### 4. Graduate Students and the REU

Recognizing the many benefits of graduate student involvement in the REU, the ISU Mathematics Department funded seven or eight research assistantships each of the three summers for graduate students who participated in the REU. These graduate students did not replace faculty involvement; normally the entire project group met together, although the graduate student led the project when the faculty member was away for a short time at a research conference.

The graduate students were encouraged to talk to the undergraduates about the graduate school application process and graduate student life, in addition to serving as research mentors. Evaluations show that the undergraduate students found the participation of graduate students to be very valuable to their experience, and the graduate students found the experience beneficial also. During the summers of 2005 and 2006, a senior graduate student served as the assistant REU manager, coordinating student activities. These students gained leadership experience and were a great help in managing the program.

As many ISU graduate students accept positions at liberal arts colleges where they will be expected to advise undergraduate research, participation in the REU is valuable training for the graduate students. (Although unrelated to the current ISU Math REU, the ISU Mathematics Department is one of the leading producers of REU site directors: Both Timothy Pennings of Hope College and J. D. Phillips of Wabash College received their Ph.D.s from Iowa State.)

#### 5. Activities

In addition to the research projects described in Section 2, the ISU Math REU had an extensive program of activities, both academic and social. During the first two weeks, the students attended several classes in the computer lab about Matlab and LaTeX. Students have heard lectures on topics varying from “The mathematics of secrecy: an introduction to public key cryptography” to “Mathematical modeling of phytoplankton”, as well as presentations such as “Graduate school: What is it *really* like?”

Social activities played an important role in enhancing the REU experience and were supported by the REU-site grant. Once a week undergraduates, graduate students and some faculty had lunch together, where extensive discussions about life as a graduate student and as a faculty member occurred. Every Tuesday and Thursday afternoon participants gathered for “pop and cookies” and conversation; once a week this was followed by a lecture or presentation. There were two major social activities each summer: a picnic at Big Creek Lake including boating, and a trip to an amusement/water park. Other social activities have varied with the summer and included participation in an intramural soccer team, ice skating, bowling, math movie night (*Fermat’s Last Tango*), a concert by a local folk singer, etc.



FIGURE 3. Racing on Big Creek Lake, 2004

The undergraduates were housed together in Frederiksen Court student apartments. This has worked well; by living together they developed strong friendships. The apartments offer the opportunity to cook, and during 2006, when all ISU REUs collaborated, there were regular student pot-lucks.

## 6. Cooperation with other ISU REUs

During 2006, there was a campus-wide group of ISU REU directors who met regularly. This resulted in many positive outcomes, including a mentoring workshop for graduate students, a campus-wide REU picnic funded by the Dean of the Graduate College at the beginning of the summer, a presentation to all REU students about graduate study by the ISU Vice Provost for Research, an end of the summer campus-wide poster session, etc. The undergraduates in the Math REU enjoyed interacting with those in other programs and this cooperation gave all the REUs greater internal visibility. It is expected that this collaboration will continue.

## 7. Goals and Program Evaluation

The goals of the ISU Math REU are:

- Provide a supportive environment where students can discover the joys of mathematical research.

- Increase the number of U. S. citizens receiving Ph.D.s in the mathematical sciences.
- Produce high quality, publishable research.

These goals have been met as measured by student surveys, data on subsequent student placement, and publications (see Section 2 for information on the latter).

Due to the need to report data separately to each funding agency, analysis of student responses was separated by funding source. The overall response from NSF REU-site grant funded students was extremely favorable. One 2005 student commented, “It was the finest summer of my life.”

Table 1 shows the average responses of all 36 NSF REU-site grant funded undergraduates to some of the evaluation questions, on a scale of 1 to 5, with 5 being “strongly agree” and 1 being “strongly disagree.”

TABLE 1. Average responses of 2004-2006 NSF REU-site grant undergraduate students

Statement	2006	2005	2004
I learned a lot from my project.	4.5	4.3	4.5
I enjoyed the REU.	4.7	4.4	4.5
I am seriously considering going to graduate school in mathematics.	4.1	4.6	3.9

We are still in the process of gathering data from the students concerning their placement after completing their undergraduate educations. Table 2 contains the information gathered so far.

TABLE 2. Fall 2006 plans of 2004-2005 NSF REU-site grant undergraduate students

Outcome	2005	2004
PhD math, applied math or statistics	3	2
Ph. D. other NSF discipline	1	1
Ph. D. other discipline	0	1
M.S. math sciences	0	1
Undergraduate	5	3
Other	2	0
No response	1	4

The 36 NSF REU-site grant funded students included 13 women. Of the five students from the first two years who are currently enrolled in doctoral programs in the mathematical sciences, four are female.

While complete data from Alliance students is not available, it is known that of the four Alliance students who participated in the 2005 ISU Math REU, one is currently enrolled in a mathematics doctoral program and one in an engineering doctoral program.