

REU in Mathematical Biology at Penn State Erie, The Behrend College

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1. Development and History of the Program

Mathematical biology is one of the fastest growing fields of mathematics, and many believe that biology will dominate the twenty-first century as physics dominated much of the twentieth century [4, 5]. An NSF sponsored REU Program in Mathematical Biology has been conducted every summer at Penn State Erie since 1998. As a primarily undergraduate institution, Penn State Erie made a conscious effort in the 1990's to establish a research group in mathematical biology, an area of mathematics that lends itself to involvement of undergraduates in research. The REU program was started by Drs. Joseph Pullet, Richard Bertram (now at Florida State) and J. Carl Panetta (now at St. Jude Childrens Research Hospital and University of Tennessee). The original intent of the program was to promote undergraduate interest in the area of mathematical biology as well as equipping the participants with the tools needed to pursue research in this field. The program was one of the first REU programs dedicated to the emerging field of mathematical biology.

In 1998, the program consisted of six students participating in a four week program, with each of the participating faculty taking one week to describe his particular research in mathematical biology. One final week was allotted for independent research. The research topics included modelling electrical activity in the pancreas, studying spiral waves on the heart (responsible for heart arrhythmias), and modelling cancer response to various chemical treatments. In the beginning of the program, more emphasis was placed on exposing students to current research in mathematical biology rather than on actively involving them in research. Part of the reason for this was an initial skepticism that undergraduates could be actively involved in meaningful research beyond "scratching the surface" of a project.

As the program developed, the emphasis began to shift from exposing the students to mathematical biology toward involving them directly in active research. The length of the program expanded to five, then six weeks. In keeping with this shift, the structure of the program was inverted, with one week of faculty instruction followed by five weeks of independent research. The faculty mentors are now Drs. Joseph Previte, Michael Rutter, and Scott Stevens. Current research topics

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include population dynamics and modelling, biomedical fluid dynamics, genomics, and bioinformatics.

2. Philosophy and Goals of the Program

A primary goal of the program since its inception is to expose the participants to mathematical biology and to the mathematical tools that are frequently used in this field. From the beginning, the creators of the program felt that mathematical biology lends itself to involvement of undergraduates in research. Indeed, the only prerequisite for participation in our program is that the student complete a course in ordinary differential equations. The number of students involved in the program is intentionally small to allow students to work closely with one another and with the faculty mentors.

Another goal of the program is to give our students an honest experience of mathematical research in this fast growing field. The hope for each project is to produce research at a level that contributes to the field and is publishable in a peer-reviewed journal in mathematical biology. Although this objective is not always met, students receive a true taste of the research endeavor. Regardless of the outcome of their work during the program, all students present their findings in a mini conference setting at the close of the program and are encouraged to speak about their findings at other undergraduate research venues. Students have also used their REU work to satisfy senior projects and honors theses at their home institutions. Those students who are interested in continuing the research that was started during the six week program remain in contact with their REU advisor well beyond the program. This is usually the case for those projects that result in a journal article. With no graduate program in mathematics at Penn State Erie, the REU program allows participating faculty to augment their research programs, providing a graduate school-like setting.

3. Program Structure

Once the students arrive on campus, the first week is used to get the students up to speed on the possible research projects. Each faculty mentor typically takes a day to introduce the students to potential projects. Students are given a choice of at least four projects from which to choose. While a certain amount of background information is given, a majority of the time is spent introducing students to the mathematical techniques and tools that will be needed to conduct the research. This exposes students to a wide range of topics even before the research begins. If time allows, a guest lecturer completes the week's presentations. At the end of the week, students decide upon which research projects they would like to be involved. Students can choose to work on more than one project and are afforded the opportunity to switch projects midstream. Recently, several students have suggested their own projects, and we have accommodated them provided that the faculty mentors were comfortable overseeing these projects. The REU also has the ability to bring in additional faculty members, either from Penn State Erie or from other institutions, broadening the scope of available projects.

The students spend the remaining five weeks of the program conducting research. Participants are encouraged to work in small groups, but independent work is also allowed. Faculty mentors work closely with the students, but much of the

research is conducted by the students independently of the faculty mentor. Students utilize such programs as MAPLE, MATLAB, and R to aide in their research. During the five week research period, students have two daily requirements: each morning, the entire group meets to discuss the research goals of each participant for the day, and each afternoon, a small presentation by each research group is made, describing what was accomplished that day. These presentations require the students to possess a level of understanding of their work sufficient to communicate to the entire group. Furthermore, the presentations involve each student in every project, thereby enabling students to move between groups.

At the end of the six week period, members of the Penn State community, as well as faculty from nearby colleges, are invited to attend a mini-research symposium in which the students present summaries of the research that they have conducted during the REU. Ultimately, we hope the students will give similar talks at regional, national, or international conferences. Students are also encouraged to pursue publication of their research if they choose. If a project is deemed publishable in an appropriate journal, the students will engage in the process of writing an article. The writing process usually takes place beyond the six week program, with significant direction from the REU mentor.

Students live on campus in university apartments and are given a food stipend. Penn State Erie treats the program participants as summer students, and allows them to utilize the same campus facilities (e.g., the gym) and organized group activities for the other students. In addition, the coordinating faculty plan a number of social activities, including picnics, baseball games, and boating trips, to encourage camaraderie among the participants and faculty mentors as well as provide a break from research. At least one day is taken to discuss graduate programs in mathematical biology. Additionally, we have invited past REU participants to discuss their graduate experiences with our students and have taken our students to visit a university with a program in mathematical biology.

4. Student Recruitment and Selection

Recruiting student applicants to the REU occurs in a number of ways. Information about all REUs funded by the National Science Foundation are aggregated by a number of web sites, and many students discover our REU through these services. We also mail a poster advertising the REU to a number of colleges and universities throughout the United States, concentrating on smaller schools that do not have graduate programs in mathematics. We also find that applicants learn about our program from former REU students presenting their research at regional and national meetings.

The average applicant pool is approximately 60 students, of which a majority are juniors and seniors. We do receive, and have accepted, some applications from freshman who have completed differential equations in their first year of study. The program has attracted students from all types of colleges and universities, from large research institutions to small, liberal arts schools. The participants from the 2005 REU are a typical representative group. They hailed from Hiram College, UCLA, Keene State University, University of Alaska at Anchorage, Hillsdale College, and Concordia College of St. Paul. Past participants have come from many parts of the country: Alaska, Washington, California, New Jersey, New Hampshire, New York, Ohio, Oklahoma, Pennsylvania, North Carolina, Mississippi, Idaho, Arkansas,

Texas, Michigan, Wyoming, Georgia, Iowa, Virginia, Minnesota, Tennessee, and Guam. Over the span of the program, only two student participants have come from the host institution, Penn State Erie, as a goal of the program is to afford a research opportunity to those who do not have such an opportunity at their home institution.

From the applicant pool we select six students. An application consists of a letter of interest from the participant, a transcript, and a letter of reference. In judging an applicant, we try to assess the student's interest in mathematical biology, prior coursework, GPA, whether the student has opportunity at their home institution to engage in research in mathematical biology, and whether the student comes from an underrepresented group. Approximately two thirds of the applicant pool is female. We have had great success in attracting both female and minority participants.

5. Examples of Research and Outcomes

In earlier years of the REU, publications with undergraduate authors did not occur. In recent years, after the program structure evolved from primarily instruction to primarily research, it became evident that undergraduates could be fully involved in the research activities of the coordinating faculty. Recently, the REU has averaged about one publication per year in a peer reviewed journal. These include [1, 2, 3] as well as two submitted articles and one in preparation.

Students have also had success presenting their research at national and international conferences. Ben Nolting (U. Alaska at Anchorage) won an award for outstanding undergraduate poster at the 2006 joint mathematical meetings in San Antonio. Brittany Parker, a senior at Mercyhurst College (Erie, PA), presented her REU research with fellow participant Tamar Wilson (Mt. Holyoke) at the Thirteenth International Conference of Forum for Interdisciplinary Mathematics on Interdisciplinary Mathematical and Statistical Techniques (2006) in Tomar, Portugal and won an award for outstanding undergraduate oral presentation. Two students from 2006 plan to present their findings in a poster session at the AMS/MAA joint meetings in New Orleans.

More importantly, around two-thirds of all participants have gone on to graduate school with about one-half pursuing research in mathematical biology or a related field (e.g., medical school). Equally important, as a result of participation in the REU, several participants have made conscious decisions not to pursue careers involving mathematical research, opting for careers that are less open ended and having more structure.

6. Feedback and Evaluation

Many of the changes to the program have taken place as a result of feedback in the form of correspondence with past participants and through proposal reviews by the NSF. The inversion in the time of instruction and the time of actual research took place as a result of this feedback. The creation of a final presentation at our mini symposium was also a suggestion that has been implemented.

All participants are formally contacted at least a year after the REU to determine the path that they chose after the REU and to solicit feedback. Students are also afforded a time of feedback at the close of the summer program in an informal brainstorming session. Participant feedback has been unanimous in assigning value

to the REU, with at least half mentioning that their participation in the REU had made a significant impact in career and graduate school decisions.

On average, three of the six participants per year continue regular contact with the participating faculty beyond the formal termination of the program. This interaction ranges from direct involvement in writing research articles and continued research, to help for preparing research presentations or papers generated at the participant's home institution. A higher percentage of students solicit advice and consultation concerning future career decisions. Several students have made or plan to make return visits to Erie to continue research that they began in the program.

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