**Proceedings of the Conference on
Promoting Undergraduate Research in Mathematics**

Mount Holyoke College Mathematics Summer Research Institute

Margaret M. Robinson

1. Introduction

Mount Holyoke's undergraduate summer research site for undergraduates was established in 1988 and has run for all but two summers since then. It is an eight-week program that consists of two research groups of five or six students each. Each group works with a faculty member on a significant mathematical problem or small set of related problems. Computation and examples play important roles in these problems and give the students a way to get started. The problems are never so straightforward that computation alone suffices. Instead they require a constant interplay between computation and mathematical theory. The role of examples to illuminate theoretical concepts is a main focus of the program. Each student finishes the program with a carefully written preprint of the summer's work. We have always published our students' preprints on our web site, worked to help students do undergraduate honor's theses extending REU results, and published in regular mathematics research journals.

Because of the traditions and priorities of Mount Holyoke, at least half of the participating students have been, and will continue to be, women. We draw students from all parts of the country and from all different sorts of undergraduate institutions. We make sure that a good portion of our students come from institutions without summer research opportunities.

Mount Holyoke College is the oldest undergraduate women's college in the country. Although small (2100 students, 200 faculty), it has a history of preparing women for graduate school in the sciences. In 1976, A. Tidball and V. Kistiakowsky wrote in "Baccalaureate origins of American scientists and scholars" (*Science* , Aug. 20 (1976)) that Mount Holyoke College had produced a larger number of women baccalaureates who eventually received doctorates in science and engineering than any other American institution in that century. A key factor in this record has been the science faculty's success in engaging undergraduates in joint research projects. As further evidence of institutional commitment, the Mount Holyoke Dean of Faculty's office and the mathematics department have provided and will continue to provide substantial matching funds for the program. These funds are used for

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student travel, for student housing in Mount Holyoke dorm rooms, for the visiting seminar speakers' honoraria, and for celebratory program meals and afternoon coffee breaks.

Primary documentation on our activities can be found on our web site at
www.mtholyoke.edu/acad/math/reu

2. General nature of student activities and the research environment

The program runs for eight weeks, starting in early June. Each student receives $3,000 for the eight weeks of work. Their housing is paid for by the program but they must buy and cook their own food, although the program does arrange at least one dinner (after the student seminar) and two lunches (one with invited speakers and one after the weekly reporting seminar) each week. We try to feed the students as much as possible. The student's all live in the same Mount Holyoke dorm with other Mount Holyoke summer research students from different disciplines. They share a kitchen with the other research students. In the mathematics department, each research group is assigned a large room equipped with a conference table, a blackboard, several comfortable chairs, desks, a library of relevant texts and papers, and dual-boot Windows/Linux computers. (Apple computers are available as well.) Other rooms are available for study and quiet. A refrigerator, microwave and coffee-making facilities are available in the department office. The entire area is air-conditioned.

Each group begins the morning by meeting with the faculty advisor to plan the day's activity. A group's daily schedule might begin with a presentation by the faculty member of new material, a presentation by students of their own progress, a discussion summarizing what has been done, or a restatement of the project's short- or long-term goals. The faculty advisor remains in touch throughout the day. The day ends with afternoon tea in the common room.

Once a week each group gives a formal progress report. The inexperience of undergraduates is never more painfully apparent than in their first presentations. We have learned over the last few years how valuable it is for them to have repeated opportunities to say what they are doing, and in the process to clarify for themselves and their friends in the other groups what their problem is about and how they approach it. In the course of the summer everyone speaks regularly and each group becomes familiar with the other group's problems.

There are also visiting speakers, most of whom are paid for with Mount Holyoke funds. In the summer of 2005, for example, there were six such visitors: David Cox on Origami Constructions (Amherst College), Tom Weston on Fermat's Last Theorem (University of Massachusetts at Amherst), Jean Steiner on Geometric Analysis (then a Post-doc at NYU), Thomas Wright on the ABC Conjecture (Graduate student at Johns Hopkins, REU 2002), Seth Sullivant on Algebraic Statistics (Harvard University), and Jason Starr on Diophantine Equations (MIT). The visitors do not just give a talk, but also spend the day with the students discussing the projects, graduate school, and mathematics in general. Some summers the visitors will bring their own summer research students with them.

The students also run and speak in their own weekly seminar series with a pizza dinner afterwards. One student volunteers to run the seminar and that student lines up the others to give talks on some unusual topic they have learned about from courses, independent work, or other summer REUs. In 2005 we had six such talks

and some of the topics were: Tilings of the plane, Ramsay numbers, Galois theory, the fundamental group and the universal covering space, representation theory, and singular homotopy.

Visits with other undergraduate research sites are often arranged during the course of the summer and almost every summer the students arrange to borrow the Mount Holyoke van for a two or three day trip to visit graduate schools. They have found that visiting graduate schools in a group is very valuable. In the past the whole REU has visited other REUs like the groups at Williams, Worcester Polytechnic Institute, Amherst College, the University of Massachusetts, and Boston University. In 2006, for example, the whole REU attended and spoke at the Young Investigator Conference at Ohio State in August. We encourage the students to present their results in the undergraduate sessions at mathematics meetings during the following year. We ask for a modest amount in our NSF grant to provide travel support so that the students can attend these meetings as well as travel during the summer to visit other REU groups. Since our travel funds are very limited, we ask the students' home institution to pay travel to the January conference and use our NSF funds only when the home institution does not have the funds available.

Five students in a group seems to work best. This size allows for diverse interactions and division of labor, yet is small enough so that no one is lost. All of our faculty except for one new faculty member have been involved in the program before. In fact most of us have led a group five or six times.

Each summer the administrative tasks are divided among the instructors. These are what one might expect: advertising the program, selecting students, finding extra funds, arranging housing, preparing the work areas and computer facilities, arranging payment of student stipends with the financial office, finding outside speakers, arranging exchanges with other REU sites, planning afternoon tea, planning social events, and so forth. Our administrative assistant organizes the incoming applications each summer (a nontrivial job, since in 2006 we had about two hundred applications for our 10 spots).

3. Student recruitment and selection

We are generally looking for students between their junior and senior year in college; we expect them to have taken the calculus sequence, linear algebra, and at least two courses beyond these such as abstract algebra and real analysis. Often one faculty member will have a more specific course requirement in mind for his or her group. The program is advertised in January. In the past, we have sent flyers to all New England college mathematics departments, and also advertised on various email listings. Recently we have not done mailings; our long history of activity, our web site, and the NSF and AMS listings continue to draw many applicants.

The applicants are selected based on the courses they have taken, their grades, recommendations from faculty members, and the applicant's statement of interest. Each faculty advisor chooses his or her own work group in consultation with the other advisors. We try to form each group so that it has a variety of talents. In particular, we make sure that each group has one or more students with extensive computer experience.

Lastly, and very important, we try to balance the number of men and women in each group (professor included). Most summers we have a Mount Holyoke student in the program but almost always she is an international student who is funded

with Mount Holyoke summer fellowship money. We encourage our students who are U.S citizens to participate in REUs at other institutions, for we consider the breadth of experience excellent for them.

4. Project evaluation

The evaluation part of our program has several parts to it. First, we collect questionnaires from each participant at the end of the program. Second, we contact them one year after the REU has ended to find out how their summer experience affected their career choice. Third, we contact them after three years to ask the same questions. Janice Gifford, in our department, is a Statistician whose primary area of expertise is educational measurement and she designed the questionnaires we use. In addition, one member of our department is in charge of the evaluation and this person writes an evaluative summary of the data from each questionnaire we distribute. A copy of our Program Evaluation is on the MHC REU website at http: \\ www.mtholyoke.edu \ acad \ math \ reu \sample_eval.pdf

All but the last four questions questions have a rating attached to them and we report the number of students who give each response along with the written answers to the last four more personal questions in our annual reports. We also investigate and respond to each negative response. We consider our program very successful to quote from the 2005 Summary: "Notably, the mean judgment of their improvement in their ability to tackle research with confidence was 3.8 [out of 4], to organize and write mathematical papers was 3.9 [out of 4], and to organize and give mathematical talks was 4.0 [out of 4]." We are happy to share any of this data and the details on our 1-year and 3-year questionnaires but, for brevity, have not included them in this paper. We use our data to make improvements in the program. In fact many of our innovations like the student seminar series and the trip to graduate schools come from student suggestions. The one reappearing suggestion that we have not been able to respond to until now is the suggestion that we air-condition the dorms and/or arrange better kitchen equipment. Although the mathematics department area and all student work areas are air-conditioned, we just had fans in the dorms. We bought our group their own refrigerator, toaster, and microwave and our students often set them up in a separate location from the dorm kitchen. Most years this works fairly well but some years the kitchen can get extremely crowded. However, this is about to change. There is a new dorm currently under construction and it will be air-conditioned. We are also in discussions with other science faculty and the administration about arranging for a summer student food plan. We recently had a much younger summer program on campus and their food plan worked well. The administration is now considering opening this option up to us too.

Our whole department participates in the REU and this is a real strength of our program. However it does mean that responsibility for the program rotates between department members every year. Each research group leader is responsible for maintaining contact with their own students, documenting the summer's work for the annual report, and for updating their own entry on the REU web site after the summer is over, as well as managing the grant finances and the program events during the summer. This decentralized control has made it hard to ensure that everyone remembers what they are expected to do as far as evaluation goes.

Having one person in charge of evaluation has ensured that each of the three pieces gets done every year in time for the annual report.

The faculty advisors of each REU group keep in touch with their students, help them continue the summer work in their honors theses, and advise and recommend them for graduate school and for prizes.

5. MHC REU Papers published since 2000

1) Alexander, Balasubramanian, Martin, Monahan, Pollatsek and Sen, "Ruling Out (160, 54, 18) Difference Sets in Some Nonabelian Groups," Journal of Combinatorial Designs, 8 (2000), no. 4, 221–231. (H. Pollatsk's 1994 REU)
2) G. Cobb and Y. Chen, "An Application of Markov Chain Monte Carlo to Community Ecology, American Mathematical Monthly, 110 (2002), no. 4, 265-288. Available from http: \\ www.mtholyoke.edu \ courses \ gcobb \ REU __MCMC \. (G. Cobb's 2001 REU)
3) P. Kim, L. Stemkoski, and C. Yuen, "Polynomial knots of degree five," MIT Undergraduate Jounal of Mathematics, v. 3 (2001) p. 125-135. (A. Durfee's and D. O'Shea's 2000 REU)
4)D. Meuser and M. Robinson, "Igusa Local Zeta Functions of Elliptic Curves", Mathematics of Computation, 71 (2001), no. 238, 815-823. Student work from 1999 REU is summarized and cited in this paper. Available from
http:\\ www.mtholyoke.edu\ robinson\reu\ reu99\ reu99.htm. (M. Robinson's 1999 REU)
5) M. Peterson and Y. Rubinstein, "Turbulence on a Desktop," Computers in Science and Engineering, May/June, 2001, pp. 86-93. Available at
http:\\ www.mtholyoke.edu \ mpeterso \reu\ 99\ reu99.html. (M. Peterson's 1999 REU)
6) B.D. Marko and J.M. Riedl, "Igusa local zeta function of the polynomial $f(x) = x_1^m + x_2^m + \cdots + x_n^m$ ", Yokohama Mathematical Journal, 51, no. 2 (2005). (Paper from student honors thesis following M. Robinson's 2002 REU)

Mount Holyoke College, South Hadley, MA 01075
E-mail address: robinson@mtholyoke.edu