

Promoting Undergraduate Research

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1. Introduction

I have been actively involved in promoting undergraduate research in the last ten years. This has been in various forms, such as directing the research of some undergraduate students individually as well as directing some REU programs where groups of students were involved in supervised research. All of these students have been supported by some funds either awarded to me as a PI or directly to the students. Although funding is not necessary to involve undergraduate students in research, the funded research may have some advantages such as providing a structured research atmosphere for the mentor and the mentees, giving a higher priority to the research conducted, requiring the accountability to the funding agency and to the scientific community, and perhaps some incentive and prestige for the student researchers. The funded undergraduate research may also help the mentor to be more selective and careful in choosing the student researchers and in determining their dedication level.

As for directing the research of individual students from one's own institution, I have come to the conclusion that it is the best to identify good candidates as early as possible, start involving them in research at an early stage, and supervise them throughout their undergraduate years. I think a long-term mentor-mentee relationship has a longer lasting impact on the student researcher. Among my undergraduate researchers it was a pleasure for me to direct the research of a bright student, Karolina Sarnowska, starting with her freshman year and almost throughout her undergraduate years. Karolina had an excellent preparation in high school and she was at the junior level when she started her freshman year at the Mississippi State University, majoring in mathematics and computer science. She is now a doctoral student in computer science at the University of Virginia.

I was the PI and director of a ten-week NSF-REU site program at the Mississippi State University during the summers of 2003, 2004, and 2005. I also directed the research of half the participants, and the rest of the participants performed their research under the supervision of my co-PI, Prof. R. Shivaaji. Twenty-five undergraduate students were involved in active research; twenty-two participants came from other institutions and three (one each summer) were local students. One of the participants was supported by my own non-REU NSF funds and the rest by

Received by the editor October 4, 2006.

the NSF-REU site grant. The concentration was in applied mathematics emphasizing topics in inverse problems, wave propagation in nonhomogeneous media, and population dynamics. The goals were to provide the participants with meaningful research experience in applied mathematics, to show them the enjoyment of doing research, to encourage them to pursue advanced degrees in mathematical sciences, and to increase participation by women and underrepresented groups. Each year eight participants were selected among about seventy applicants based on the credentials they submitted. I tried to use the following question as a guide to select the participants: Which applicants can benefit the most from the program? We had a diverse group of participants; twelve women and thirteen men, one African American female and one American Indian male, a seventeen-year old participant who was among our best, a few from poor families, some from top schools and some from schools with no opportunities. The research program was supplemented with some social activities, weekly colloquia, trips, dinners, and other events. The participants were treated like advanced graduate students in a typical research university working closely with their research supervisors and enjoyed our program.

2. The 2006 Summer MAA-NREUP

I moved to the University of Texas at Arlington in August 2005. With my colleague Prof. Minerva Cordero-Epperson I ran the 2006 MAA-NREUP (National Research Experience for Undergraduates Program), a six-week summer research program for minority undergraduate students in mathematics, sponsored by the Mathematical Association of America with funds provided by the National Science Foundation, the National Security Agency, and the Moody's Foundation. Since the duration of the program was relatively short, we had to arrange all the logistics ahead of time. My previous experience in directing the NSF-REU site program was very helpful. We knew exactly what we wanted to do and planned everything carefully so that the participants would fully concentrate on research.

We chose the participants carefully to have a balance. All the four participants were Hispanic American, two men and two women, two from our own institution and two from other institutions in the region. They were all considered to be good students, two with no previous research experience at all, two with some prior exposure to research, only one of the four had ever given a public presentation. I communicated with them frequently before the program so that they had a full understanding that they would not undertake any other responsibilities during the program and would fully concentrate on research. I think this is an important matter that needs to be clearly indicated to the participants before the start of the program; some participants might assume that they could, for example, have a part-time job for extra income during the weekends or some evenings. In my opinion, this would defeat the purpose of the program and the program would simply be viewed by the participants as nothing but a source of income without any long-term benefits. We were able to expect and demand that the participants would not hold any other responsibilities thanks to their generous stipends in our budget.

The MAA-NREUP research topic was related to the direct and inverse problems in human speech, one of my current research interests. Every weekday morning I met with the participants in one of the seminar rooms exclusively reserved for our program. Each meeting started promptly at 9:00 a.m. and usually lasted till 10:30

a.m. I explained the research problem and identified the goals. Since the topic was interdisciplinary, techniques from various areas of mathematics were used. The participants were pleased for various reasons: They were able to put their knowledge from calculus, linear algebra, and differential equations in use; they were exposed to partial differential equations, complex variables, integral equations, and numerical analysis; they were also exposed to acoustics and linguistics.

Every weekday afternoon during 3:30-4:30 p.m. the participants attended our computer laboratory, staffed by three graduate student mentors, all of whom had some prior experience in teaching and mentoring undergraduate students. The mentors were also familiar with the research topic because they took my special topics course on inverse problems in the spring semester of 2006. We avoided any micromanagement on purpose and let the graduate students interact with the participants to accomplish the clear goals we set: The participants would learn and be fairly proficient in LaTeX, Beamer, Mathematica, and Matlab, they would prepare a joint report in LaTeX based on their research (it would be acceptable if the report could not be put in a final form by the end of the program, the polishing of the report and its preparation for publication could be done after the program), and they would prepare a public presentation in Beamer at the end of the program. We reserved eight of the computers in our computer laboratory to use exclusively in our program. We installed MikTeX, Beamer, and WinEdt on those computers before the program started; the computers were already loaded with Mathematica, Matlab, Excel, and various other software. After the first half of the program, it turned out that the participants were spending more time in the computer laboratory, especially towards the end of the program, when they were doing symbolic and numerical computations and also preparing their presentation.

In the summer of 2006 I offered a seminar class on Monday and Wednesday evenings during 5:00-7:00 p.m. for thirteen of our graduate students. Since this was very relevant to our MAA-NREUP participants, we asked them to attend this class. The seminar class was intended to improve research and presentation skills of the students and to explore some research tools available for mathematical scientists. The topics covered included:

- 1) mathematical organizations (AMS, MAA, etc.), institutes (MSRI, IMA, etc.)
- 2) Mathematical Reviews, MathSciNet, Zentralblatt, CMP, MSC, PACS
- 3) mathematical typesetting, TeX, LaTeX, WinEdt, Beamer
- 4) mathematical conferences, meetings, attendance, funding, organizers
- 5) journals, writing papers, submission, refereeing, editorship
- 6) joint research, interdisciplinary collaborations, communicating with peers
- 7) teaching, record keeping, interacting with students, grading, mentoring
- 8) grants, fellowships, funding, proposals, submission, budget, overhead
- 9) dissemination of research findings, talks, posters, web pages
- 10) graduate school, application, PhD, advisor, qualifying exams, thesis
- 11) academic and industrial positions, tenure, promotion, faculty rank
- 12) software, Matlab, Mathematica, Maple, SAS
- 13) jobs, how to apply, EIMS, resume, cover letter, cover sheet, interview
- 14) library resources, information resources, arXiv, etc.

There were various additional activities in our 2006 MAA-NREUP. For example, one of our science librarians gave a special presentation to our participants in using library and online resources. We treated our participants to some lunches

and dinners, which provided excellent mentoring opportunities in a friendly environment. Some additional information on our MAA-NREUP is available at the url <http://omega.uta.edu/~aktosun/nreup>. Overall, this MAA-NREUP was really a rewarding experience for us all. We all worked very hard and provided our participants with an excellent environment to attract them to mathematics at the graduate level and perhaps also beyond that. They were treated like advanced graduate students in our department and they also enjoyed all the perks our faculty and graduate students do (access to printing, photocopying, secretarial help, computer accounts, phone, departmental laptop computers, supplies, etc.) We arranged all these on purpose so that the participants would get a taste of being a graduate student or perhaps a faculty member and see for themselves whether they would like it or not.

3. Evaluation of our 2006 MAA-NREUP

Our program has been evaluated externally by an independent group at the Oregon State University through various questionnaires. Independently from that evaluation, a week after our program ended we requested input from our participants and asked them to send their comments to our secretary, who would remove the identity of the evaluators and forward the comments verbatim to us.

The e-mail I sent to our MAA-NREUP participants requesting their evaluations was as follows:

“Thank you for participating in the 2006 NREUP during June 11-July 22, 2006. Would each one of you please provide us with an evaluation of our program in a few paragraphs? At the end of your evaluation please assign a rating for the program by using the scale 5, 4, 3, 2, 1 (5 excellent, 4 good, 3 average, 2 poor, 1 very poor). In your evaluations you may comment on various aspects of the program such as:

- 1) The quality of research and supervision in the program.
- 2) What were your expectations before the program? Have those been met? How may have you benefited from your participation in the program?
- 3) Logistics (stipend, office space, computer lab, working environment, dormitory, etc.)
- 4) Has the program had any influence on your plans regarding graduate study, careers, future research, etc.?
- 5) Have you been able to go from a dependent status to an independent one as far as research is concerned? Has the program been helpful to you to go in that direction in future research endeavors?
- 6) Please comment on new knowledge or skills you may have learned or gained from this program (research, technical, computational, library, written, oral, critical thinking, etc.)
- 7) Would you recommend the program to other undergraduate students? Please comment if you have any suggestions for improvements.”

All the four participants responded and sent their evaluations to our secretary by e-mail. I quote the four evaluations verbatim, which indicate what and how much the participants have gotten out of our program.

Evaluation by Participant 1:

“The first word that comes to mind when writing this evaluation is outstanding. This six week experience was unbelievable due to the amount of support and

dedication from the people from the MAA and the University of Texas at Arlington. Before the program began, I did not set particularly high expectations. Being that this was my first REU program, I did not prepare myself for the invaluable experience and knowledge I would gain. After reading one of the first e-mails from Dr. Aktosun, the program did not sound all that mathematically extensive. He really only stressed that previous experience in linear algebra would be needed; therefore, my first impression was that the research would be focused on applications of lower level college mathematics. As we dipped into upper and graduate level mathematics, I quickly noticed that my expectations were incorrect, but I'm glad to see that they were. This experience has broaden my view of mathematics tremendously and sparked a brighter flame in my enthusiasm for the field. While I was quite seriously contemplating attending graduate school, I was not really firm on that decision and I did not have a clear understanding of the opportunities out there after graduation. After the experience in this program, I have gained strong belief that I belong in graduate school and have something to offer to the mathematical community either professionally or academically. I also must commend all the logistical effort that the people at UTA put into running this successful program. The housing and offices were great, and everybody on campus, students and faculty, gave a really good impression of the university. When compared to the other university environments that I have been around, I think that UTA is a good campus to host this program. In fact, I am quite interested in applying to UTA for graduate school. One of the main goals of this program is to give participants a taste of research. I think that this program has done so, but I am not completely confident in my abilities as an independent researcher. While I really enjoyed the group aspects of the program and would list it as an essential asset to the program, the research independence goes down when working as a group. I think that by working as a group we limited how deep we each connected with the research individually. The overall experience of the program gets a strong 5 from me. My mathematical knowledge and experiences have grown greatly as a result of this program. I have learned LaTeX, Mathematica, MATLAB, Beamer, elementary differential equations, and inverse problem theory. I have gained experience by giving my first mathematical presentation, having a working relationship with four of my peers, writing a paper detailing our research, and being submerged in the lifestyle of research mathematicians.

I would definitely recommend this program and similar programs to all undergraduate math students who have determination to be successful in the math field, and I would tell them to take full advantage of the opportunity.”

Evaluation by Participant 2:

“My experience at the NREUP was wonderful because everyone in the department was very encouraging. The directors and students I worked with were helpful in my understanding of the research problem so that I could better contribute to the group in the goals we set for the summer. The supervision given by the directors and mentors was critical for me since I have a hard time concentrating for long periods of time. I didn't expect this program to be easy; I knew it would take work and dedication to complete the desired goal. I benefited from this program by learning what a graduate student does, how math faculty interacts, and what I could achieve in such a short time. I had wanted to go to graduate school before I started this program but didn't know the type of life I would be living. This

program gave me that opportunity and experience from talking to the graduate mentors, the office, stipend and spending countless hours in the computer lab. I still don't believe I am capable of doing independent research but this has improved my self-esteem in the math I can do. The program set up was very helpful in that I had a wonderful place to stay, an office to take care of personal business, and a stipend to eat and pay tuition for the fall semester. The mathematical software we learned were very beneficial since I had heard what they were but had never really worked with them. I know I will use them in the future with research and graduate courses. This program is very beneficial to the undergraduate student and I would recommend it to any Hispanic striving to be a mathematician. Overall the program, in my opinion, was a success; I would rate it a 5 (excellent)."

Evaluation by Participant 3:

"My overall rating of the program: 5

Before the beginning of the program I was expecting to have some hands-on experience and to improve my team work skills. Through out the program, my expectation were not only met but surpassed. I really had "a feel" of how it is to work in the field and to work with a team truly willing to contribute to the effort. Also, the software training we received is priceless; I'm already using it to make simulations.

Furthermore, the working environment was very friendly, the housing provided was very nice, and the stipend very generous.

I would certainly recommend this program to other undergraduates."

Evaluation by Participant 4:

"The research topic selected for the program was excellent because it applied mathematics classes that we had taken in the past. Dr. Aktosun's expertise in this topic, his patience and great teaching skills made this experience painless, memorable, and rewarding.

I expected the program to be passive learning, similar to that of class room environment. The program exceeded my expectations by providing an active learning environment where no question was too basic. The main objective was to learn. The program gave me a small insight as to what a Professor and a Graduate student do when they are not teaching. I'm seriously considering pursuing a Masters and then

I learned new software programs (Matlab, Mathematica, Latex, Beamer), reviewed and/or re-learned math taken in the past (Differential Equations, Partial Differential Equations, Linear Algebra, Calculus). Our final exam was to give an oral presentation of the mathematical problem/solution using the tools we learned in the program in front of peers, graduate students and professors.

The icing on the cake was that we were paid to attend the program! Students that are considering a higher degree would pay to attend a similar program because the insight would help them decide whether this is what they are interested in.

Overall, the program was excellent! I would definitely recommend the program to other undergraduates. Thank you for the opportunity to participate!"

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