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The REUT and NREUP Programs at California State University, Chico

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Since 2003, we have been running a summer REU program at California State University, Chico. We place particular emphasis on participation by women and minority students as well as high school teachers. Our six week program is divided into phases modelled on Polya's four stages of problem-solving. Our evaluation plan includes a case-control observational study of student career choices and a Leikert-scale survey that attempts to measure effects on perception of mathematics. Following a brief overview of the history and goals of our program, we describe below the nature of participant activities, recruitment, and our evaluation plan and outcomes.

History and Goals

In the summer of 2003, CSU, Chico served as a pilot site for the MAA's National REU Program (NREUP). In addition to successfully renewing NREUP funding every year since then, 2004 was the first year of a three year REU award from the NSF. We are currently seeking to renew this funding.

With NREUP support we recruit students from minority groups (i.e., African Americans, Latino Americans, American Indians, and Native Pacific Islanders). As this grant does not include travel funds for participants, we target students from the North California region. A total of fifteen undergraduates have joined us in the four summers of NREUP support.

The focus of the NSF REU award is the integration of undergraduates and high school teachers. Hence, we refer to this as an REUT (i.e., a combined REU and RET, or Research Experiences for Teachers). Each summer we engage six undergraduates and two teachers to work in teams on research projects. We feel that the skills and experiences of these two populations complement each other. In particular, the teachers are adept at presenting the results of the research and can tap into a certain mathematical maturity. The undergraduates, on the other hand, have had more recent exposure to higher mathematics and tend to bring a lot of enthusiasm and drive to the enterprise.

We have the following specific objectives for our REU programs:

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- Encourage undergraduate students, especially those from underrepresented groups, to pursue careers in sciences and engineering, including teaching.
- Help to better prepare students to pursue advanced degrees and careers in the sciences.
- Provide in-service teachers with a research experience that will foster excitement about mathematics, increase content understanding, and inspire pedagogical innovation in their classrooms.
- Promote and enhance mathematical research involving undergraduates at CSU, Chico.

We will next discuss how participant activities are designed to support these objectives.

Nature of participant activities

Our program lasts for six weeks each summer. This is mandated by NREUP funding, but also works well for the teachers who typically must balance many demands on their schedule during the summer months. The relatively short time frame requires well thought out research problems that allow participants to "hit the ground running." For the first two years of the program, the research focus was knot theory. In 2005, participants were split into two groups, one investigating knots and the other statistics. We again had two research groups in 2006, knot theory and mathematical modelling.

We typically have twelve participants each summer who are split into four groups of three. Each team is led by a faculty member who helps participants progress from dependent learners to independent investigators by modelling and explicitly discussing Polya's four stages of problem-solving: understanding the problem, devising a plan of attack, carrying out the plan, and reflecting on the work. We recognize that students progress at different rates, and there will be overlap between successive stages; however, our activities are structured to facilitate the smooth progression from one stage to the next at a pace appropriate to the competence of each participant.

Following that model, in the initial stage, the team leader offers a mini-course related to the team's mathematical focus area. This provides an opportunity for the team leader to give participants additional relevant background material, introduce computer software, evaluate the competence of each participant, foster a supportive team environment, and in general ensure the group has the necessary tools to carry out the research project. The team leader concurrently begins to introduce specific or general open research problems in the appropriate content area; students are encouraged to begin their own exploration right away. In their first step towards independence, the participants are asked to select a research problem. At this point the participants may be given some research or expository articles to read in order to gain understanding of their particular problem. These research articles can be discussed with the faculty leader in a group setting; participants begin to learn how to read journal articles, a skill that usually requires much practice. These informal discussions help the faculty member ensure that each member of the team "understands the problem" and is thus ready for the next stage.

In the second stage, the faculty member takes a step back by gradually transitioning from group director to group member, allowing the team more flexibility in deciding its own path. The team is responsible for "devising a plan of attack,"

which includes developing research directions and allocating responsibilities. The faculty member contributes to discussions during informal meetings and helps guide the group in fruitful directions without imposing his own ideas. The faculty leader also ensures that each individual is contributing to the development of the team's plan and has a reasonable share of the responsibilities in carrying out the attack. This stage culminates in a presentation of the team's research problem and plan of attack.

In the third stage, the faculty member steps back even further; having helped guide the group in the development of a plan, he now allows the group to carry out that plan with minimal assistance and acts primarily as an advisor as the team becomes self-sufficient and takes ownership of all aspects of their particular problem. Here, both teachers and undergraduates are confronted with their lack of experience in doing mathematical research. They can help each other to overcome this hurdle and learn to be independent mathematical explorers.

In the fourth and final stage the group "reflects" by jointly authoring a written report and preparing a presentation on their research including: a clear statement of their problem, their plan of attack, any obstacles which were encountered, results they obtained, and perhaps directions for further investigation. This stage begins at the end of the fifth week with two short workshops: one on writing technical reports and a second on presenting research to a mathematically literate audience. In this stage the faculty member's role is primarily to give advice and answer questions that may arise during this process. The reflective stage will likely continue after the term of the REUT, as students work with their team leader to prepare a manuscript for publication. As appropriate, we submit their papers to research journals or journals for undergraduate research.

These team efforts are complemented by a weekly series of invited talks which all students attend. The guests are usually professors from research universities in the region. These invited talks are paired with student presentations and followed by dinner. This informal setting often leads to lively table conversation as students share their progress with our guest. In addition to making two oral reports during the course of our program, many of our students also present their research at national and regional conferences.

Participants are housed in an eight bedroom apartment-style dormitory that provides a large kitchen, dining room, and living area. In addition to on-going opportunities for interaction due to the shared living quarters and lab space, we organize social activities such as softball games and visits to local theatres and cinemas.

Recruitment

Our focus on minority students from our region and high school teachers present particular challenges for recruitment. We have been successful in attracting teachers from around the country by placing advertisements in the NCTM Bulletin. We also advertise in the AWM Bulletin and on the SACNAS (Society for the Advancement of Chicanos and Native Americans in Science) web-site in an effort to recruit women and minority students. However, we have found that the most effective way of recruiting local minority students is to send e-mails directly to the math undergraduates of institutions in our area.

Program Evaluation and Outcomes

In addition to the desirable and measurable outcomes of participant publications and talks or posters given at professional meetings, we also evaluate the success of our project by measuring its impact on the participants. For the purposes of assessing how well we are meeting our project goals we separately consider:

- effect on participants' perception of mathematics and research
- effect on undergraduates' career choices
- effect on teachers' instructional strategies.

Our primary assessment method is self-reporting surveys.

To measure the effect on participants' perception of mathematics and research we have all participants complete a Leikert-scale questionnaire at the start of their experience, at the end of their experience, and during the following academic year. In addition, we ask teachers to report on new in-class activities or modifications to classroom practices in the year following their summer experience

As a way to measure the effect on undergraduates' career choices, we have designed a case-control observational study. To select participants we group desirable applicants into pools of three from which we select one student to participate. In this way we have, for each participating student, two non-participants with similar (as similar as possible) backgrounds. After the REU experience we mail surveys to both the participants and their non-participating counterparts. Participants are also given a survey at the start of the six-week program and another at the end. To give the reader some idea of these assessment techniques and the survey results we discuss results from the summer 2005 program. The teachers who participated in the RET also filled out surveys during the program and during the next academic year.

Surveys were mailed to all seven of the undergraduate participants as well as twelve non-participants. To encourage response a gift certificate for purchasing books from an on-line vendor was included with the survey. This was highly successful as a motivator, despite the fact that we did not require filling out the survey in order to receive the certificate. Of the seven participants all responded and eight of the twelve non-participants returned a survey.

Effect on undergraduates' career choices: Not too surprisingly, most of the students who applied to the program ended up applying and being accepted to a graduate program in the mathematical sciences. Of the seven participants from summer 2005, all but one had applied to a graduate program in a mathematical science (one became a senior in fall 2006). Of the six participants who applied to a program, all but one has been accepted to at least one program. The non-participants have similar numbers: six of eight applied and were accepted to a graduate program in a mathematical science; one has become a high school teacher and the other has taken a job in industry.

Effect on perceptions of mathematics research: In an attempt to measure participants' perception of mathematics research, a survey was designed which consisted of quotes about mathematics and mathematics research – some from famous mathematicians. Students were asked to indicate the degree of their agreement with the statement (strongly disagree, disagree, neutral, agree, or strongly agree). This survey was filled out three times: once at the start of the program (before

we said anything), once at the end of the six-weeks and once near the end of the following academic year. We won't report a full analysis of the data, but give an example. One item stated, "Mathematicians rarely make guesses." Comparing responses from the first day to those on the last day of the program, five of the seven students had moved one step in the strongly disagree direction. Four of the seven were neutral on this statement on the first day of the program, on the last day these four disagreed with the statement and by the time of the mailed survey two of these had moved to strongly disagree. Statistical analysis indicates a significant change in the response to this item in the pre and post survey. This seems to indicate a change in perception of mathematics research due to the experience. The responses to this item on the first day survey are also statistically different from those on the mailed survey nearly one year later. This indicates that the changed perception lasted or was reinforced elsewhere.

Effect on teachers: Three teachers participated in the 2005 RET. What is probably most informative is the responses from the survey given near the end of the following academic year. All three teachers had incorporated specific activities in their classroom that were based on their summer research. Two of the three teachers said the experience changed how they teach in that they incorporated more discovery based activities in class. All three teachers indicated they enjoyed working with undergraduates.

Conclusion

In closing, we remark that in addition to being a positive experience for all participants and faculty involved, the REU programs are having an important effect on the research life of the CSU, Chico math department. In 2003, we were virtually alone as proponents of undergraduate research. Today, the idea of collaborating with undergrads has been taken up by many in the department and a contingent of five of us have been involved in requesting renewed funding. We also make a point of holding a few positions open each summer for our own students. These students return to their classes in the fall eager to share their experiences with peers and with a huge boost in self esteem and confidence. We would like to take this opportunity to thank the funding agencies (the National Science Foundation, the National Security Agency, and the Moody's Foundation) for all that these programs have done for participants, faculty, and our department.

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