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The Trinity University Research Experiences for Undergraduates in Mathematics Program

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Trinity University is one of the Southwest's leading undergraduate institutions. For the last 14 years, U.S. News and World Report has ranked Trinity number 1 among comprehensive universities in the Western part of the United States. Undergraduate research is central to the overall goals and priorities of the academic program at Trinity University and Trinity's Chemistry, Computer Science, Biology and Mathematics Departments have a long history of substantial external funding for such activities. As evidence of this strong commitment to summer research, during May, June and July of 2006, 97 undergraduate students conducted research on Trinity's campus; 80 of them were Trinity students, 17 were from other institutions. Their research in Biology, Chemistry, Engineering Science, Mathematics, Biochemistry, Physics, Computer Science, Psychology, Neuroscience, Geosciences and Political Science was funded by 11 different external agencies[1].

The Mathematics Department at Trinity University recognizes and endorses the University's overall goals as described above. The Department has functioned as an NSF supported REU Site under three different grants (from 1997 to 1999, 2001 to 2003, and 2004 to 2006). The program has become an intricate part of the Department and has played a key role in strengthening and improving the mathematical education we offer our own students. While the accomplishments of our Program have been detailed in publications such as *Math Horizons*[2] and *Focus*[3], we operate our program on the principle that no matter how successful we are, there is always room for improvement. Our goals have remained consistent over our 9 REU Programs.

• To provide 12 student participants per year with an understanding of, an appreciation for, and an experience in the nature of mathematical research and the life of a mathematical researcher, to a degree that encourages them to pursue the study of the mathematical sciences on the graduate level.

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[1]Information in the first paragraph was provided by the Trinity University Office of Academic Affairs or taken from their summer research web site `http://www.trinity.edu/org/student_summer_research/index.htm`.

[2]S. T. Chapman, REU Spotlight: Trinity University, *Math Horizons* **11**, pp. 26–27, 2004.

[3]M. Martelli, The undergraduate student poster session, *Focus* **25**, p. 23, 2005.

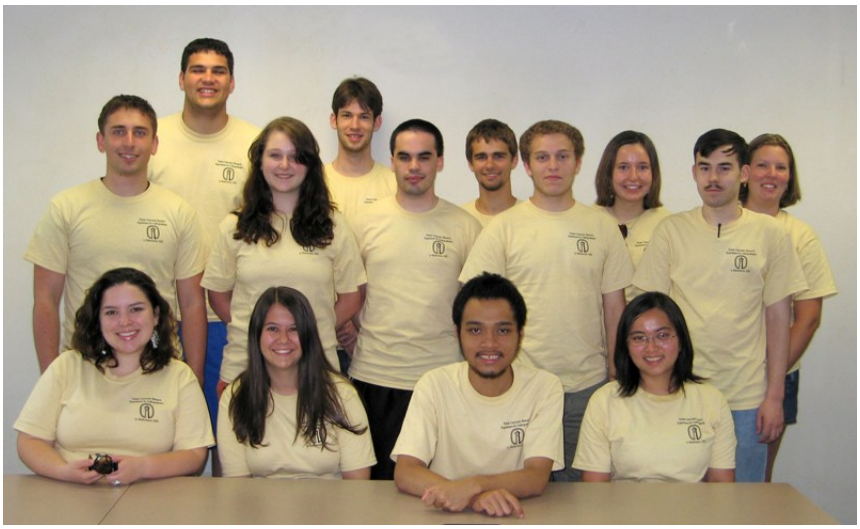

FIGURE 1. The 2006 Trinity REU Participants

• To offer these experiences with an eye toward students who do not typically have these opportunities. Of particular interest are students who are either female or a member of an under-represented group.
• To develop in each participant superior skills in mathematical writing, oral mathematical presentation and poster design.
• To produce quality mathematical work appropriate for publication on our web site or in undergraduate research journals and, when possible, in higher level research journals.
• To extend the research experience beyond the 9 weeks at Trinity by motivating the students to present their REU research at a regional/national meeting.
• To gain experience in the use of computers and their interaction in mathematical research.
• To immerse the participants in the culture of mathematics and instill in each member a lifetime appreciation of the value of collegiality and group interaction.

While the primary focus of our Program is mathematical, the Trinity mathematics faculty believe deeply that a strong recreational component of the program is vital to its success. Our past programs have featured a strong schedule of activities that included a cultural tour of the downtown area, weekly flag football and ultimate frisbee contests, social gatherings at faculty member's homes, and a tubing trip down the Guadalupe River. One of the more popular parts of our previous programs has been the daily 3PM refreshment "Break," which gives all participants and faculty an opportunity for camaraderie and conversation.

We traditionally break our 12 students into 4 research groups, which vary (according to faculty availability) but usually consist of Algebra, Combinatorics, Discrete Dynamical Systems and Mathematical Biology. Students are selected for the Program by the Individual Project Directors and hence are aware of their assigned Projects when they accept their summer offer. Participants are housed in campus dormitories and roommates are assigned outside of each participant's research group in hopes of developing a higher level of interaction between students

working on different projects. Once participants arrive on campus, they are assigned a work area in the Mathematics Department's computer laboratory, which includes for each participant a Dell PC dedicated to their personal summer use. We believe strongly in an intense opening week of the Program. The first morning includes a comprehensive orientation of the campus, the local area and the procedures of the University and the Program itself. The initial meeting of participants and their Project Directors takes place early the first afternoon, and is followed by a Panel Discussion of 4 to 5 Trinity REU Alumni. Group meetings continue every morning for the remainder of the first week as faculty review essential introductory material. From Tuesday to Friday, the remaining first week afternoons will consist of two colloquia. The first is a "Topic Colloquium" is delivered by one of the participating faculty and is intended to give all participants an introduction to that person's area of research. A second "Enrichment Colloquium" is directed toward broader issues that impact the participants' mathematical development,such as (a) how to give a successful mathematical presentation, (b) how to choose and apply to a graduate program in the mathematical sciences, and (c) getting started with the typesetting system LaTeX .

The remaining 8 weeks of the Program are dedicated to the completion of each group's research project. Participants will begin in early May to receive reading material and suggested problems from their Project Director. During the first week's meetings between the Project Directors and their research groups, the faculty will review this material and discuss the positive and negative aspects of each proposed research project. Early in the second week, each research group will make a decision on the specific problem/topic that the group will pursue. Our past experience indicates that this "choice" is an important aspect of the Program. After the first week, research groups traditionally meet daily with their Project Directors. At the end of the second week, each research group will give an oral presentation (no more than 30 minutes in length) explaining their selected problem to the entire group. A written document supporting the presentation will be submitted to the Project Director. Each Project Director evaluates their group's oral presentation and written description and communicate this evaluation in writing to the research group.

During the fifth week, each research group presents a written midterm progress report to their Project Director. The report will not merely be an outline of the progress to this point, but should contain arguments supporting the student's research. They will present an oral progress report (of no more than 30 minutes) to the entire REU group and again each Project Director will evaluate both the oral and written reports and communicate this finding in writing to their group. This process will culminate during the ninth week when the group gives their final 60 minute oral presentation and turns in their final written report. The written report becomes part of Trinity University's *Mathematical Technical Reports* series and be posted in the REU Project Archives on our web site.

We have put a substantial amount of time and energy into the development of our web resources for student recruitment. This has paid off as the number of applications we have received has risen drastically since 2001. Moreover, since we began tracking our web site in February of 2003, the site has had over 19,000 unique hits [4]. The web site is one of our main tools for recruiting. It contains an

[4] `http://extremetracking.com/open;sum?login=tureu`

indepth description of the Program, including descriptions of the available research projects, photographs from past programs, a summary of past participant current activities, a summary of written student evaluation remarks, an archive of past REU projects, a summary of published research, and the forms that prospects need to apply. We plan to continue our important emphasis on the recruitment and participation of female students and students from under-represented groups. Our goal is to *exceed* the figures of 44% participation by females and 17% participation by under represented groups which were achieved by both the 2001–2003 and 2004–2006 Programs. Some data concerning recruiting is contained in Table 1.

TABLE 1. Summary Data for Years 2001-2006

Years	# of Applicants	# of Offers	Male Participants	Female Participants	Participants from Under-Rep. Groups
2001–03	330	46	20	16	6
2004–06	381	45	20	16	8
Total	711	91	40	32	14

Our system of program evaluation is four tiered and includes 1) an anonymous written evaluation by the participants and Graduate Mentors, 2) an exit interview between each participant and Program Personnel, 3) comments and opinions solicited from Program Alumni, and 4) an external review by a mathematician of national stature. Our written evaluation consists of both numerically scored and free response questions. We set as a goal an average response from the participants of at least 5.0 on each scaled question. Should the average on such a question fall below this level, a written plan addressing corrective measures will be included in our following yearly progress report to NSF. We include below comments from our 2005 external review.

Here are the highlights of the program: a rigorous and fair selection process that ensures the presence of highly-motivated student participants, a group of dedicated faculty mentors with the experience and expertise to select challenging projects that match student interests and abilities, good physical facilities that encourage academic interactions and facilitate the exchange of intellectual ideas, the establishment and maintenance of a strong communications network with participants from prior years. ... I was particularly impressed by the strong sense of community that appears to have developed among the student participants. ... The development of such a group dynamic can clearly be attributed in my opinion to the enthusiasm and guidance provided by the faculty mentors. ... The Trinity REU program is to be commended for its serious efforts to encourage participation by a diverse group of students. There is clearly a healthy balance of student participants both in terms of gender and ethnicity. ... There is no question that the program is an unqualified success. - from 2005 External Review by **Efraim Armendariz, Professor and Chair, Department of Mathematics, University of Texas at Austin**

Since its inception, the Trinity REU has hosted 88 different participants. As of the submission of this article, 67 have received their undergraduate degrees and 51 of those students (or 76%) have enrolled in some type of graduate program.

Of the 51 REU participants who began graduate study, 36 (or 71%) enrolled in a program in pure or applied mathematics, 5 enrolled in computer science, and 2 or less enrolled in each of the fields of law, logic, engineering, mathematics education, physics, statistics and economics. Of the 36 who began in mathematics, 28 (or 78%) enrolled in programs which are ranked as Group I by the American Mathematical Society. We are particularly pleased with the following statistics: (a) of the 26 female REU participants who have received their undergraduate degrees, 22 (or 85%) have enrolled in graduate study, (b) of the 6 REU participants who identify themselves with under-represented groups and have received their undergraduate degrees, 4 (or 67%) have enrolled in graduate study. The group which has completed our program has received further distinction. Two of our participants (M. Holden (2002) and W. Meyerson (2003)) completed in 2005 the prestigious Tripos III Program at Cambridge University. Two more of our participants have received Homeland Security Fellowships to begin their graduate study (P. Baginski (2001) and K. Cervello (2004)). Two other students (D. Morris (2002) and G. Harrison (2005)) have spent time overseas supported by Fulbright Fellowships. In total, eight of our participants have completed the Budapest Semesters in Mathematics Program (T. Moore (2002/3), M. Bannister (2003), T. Landry (2003), J. Chaika (2003), B. Finklea (2003), P. Blain (2005), E. Treviño (2005), C. Vinzant (2005) and M. Gallant (2005)). Another participant (J. Bauman (2006)) has completed the Mathematics in Moscow Program.

During the 2003 program, we began to emphasize student oral presentation and poster design skills. We added improvement of these skills formally as a goal to our 2004–2006 proposal. We believe that this emphasis has paid off. Over the past 3 years, 12 of our participants have presented talks at the annual Young Mathematicians Conference (YMC) at Ohio State University. During 2003 and 2004, 7 more of our participants presented talks at the annual Big Sky Conference on Discrete Mathematics at the University of Montana-Missoula. Beginning with the January 2003 joint meeting, 12 participants have presented posters at the annual AMS-MAA Undergraduate Poster Session. Several of our former participants have won awards for presentations, including 6 Meritorious Awards of $100 each for posters at the AMS-MAA Undergraduate Poster Session.

Since our initial program in 1997, 16 papers have been published or accepted in regular research level journals which contain Trinity REU participants as co-authors. As of the submission of this article, 3 other papers have been submitted and numerous papers (including all those from work in the 2006 program) are in preparation. We are particularly pleased with the following statistics: (a) of the 75 REU participants prior to the 2006 program, 35 (or 47%) are a co-author of a published or accepted paper in a regular research level journal, (b) of the 30 female participants prior to 2006, 18 (or 60%) are a co-author of a published or accepted paper in a regular research level journal, (c) of the 11 participants from under-represented groups prior to 2006, 4 (or 36%) have a similar co-authored publication.

Publications Resulting From The Trinity REU Program

(Undergraduate co-authors marked with an asterisk-*)

(1) J. Amos*, E. Treviño*, I. Pascu*, V. Ponomarenko and Y. Zhang*, The multi-dimensional Frobenius Problem, to appear in *Advances Appl. Math.*

(2) P. Baginski, S. T. Chapman, C. Crutchfield*, K. G. Kennedy* and M. Wright*, Elastic properties and prime elements, to appear in *Results Math.*

(3) P. Baginski*, S. T. Chapman, K. McDonald* and L. Pudwell*, On cross numbers of minimal zero sequences in certain cyclic groups, *Ars Combin.* **70**, pp. 47–60, 2004.

(4) P. Baginski, S. T. Chapman, M. Holden* and T. Moore*, Asymptotic elasticity in atomic monoids, *Semigroup Forum* **72**, pp. 134–142, 2006.

(5) M. Banister*, J. Chaika*, S. T. Chapman and W. Meyerson*, On a result of James and Niven concerning unique factorization in congruence semigroups, to appear in *Elem. Math.*

(6) M. Banister*, J. Chaika*, S. T. Chapman and W. Meyerson*, On the Arithmetic of Arithmetical Congruence Monoids, to appear in *Colloq. Math.*

(7) C. Bowles*, S. T. Chapman, N. Kaplan* and D. Reiser*, On Delta Sets of Numerical Monoids, to appear in *J. Algebra Appl.*

(8) A. Brown*, A. Gedlaman*, A. Holder, and S. Martinez*, An Extension of the Fundamental Theorem of Linear Programming, *Oper. Res. Lett* **30**, pp. 281-288, 2002.

(9) L. Cayton*, R. Herring*, A. Holder, J. Holzer*, C. Nightingale*, and T. Stohs*, Asymptotic Sign Solvability and the Dynamic Nonsubstitution Theorem, to appear in *Math. Methods Oper. Res.*

(10) K. Cervello*, D. Terry*, V. Ponomarenko and L. Zhu*, The Extraction Degree of Cale Monoids, *Semigroup Forum* **72**, pp. 149–158, 2006.

(11) S. T. Chapman, V. DeLorenzo* and H. Swisher*, On the asymptotic behavior of irreducibles in block semigroups, *Semigroup Forum* **63**, pp. 34-48, 2001.

(12) S. T. Chapman, J. Herr* and N. Rooney*, A factorization formula for class number two, *J. Number Theory* **79**, pp. 58-66, 1999.

(13) S. T. Chapman, M. Holden* and T. Moore*, On full elasticity in atomic monoids and integral domains, to appear in *Rocky Mountain J. Math.*

(14) J. Cuomo*, N. Nwasokwa* and V. Ponomarenko, Jump Systems and Manhattan Polytopes, *Australas. J. Combin.* **31**, pp. 135–143, 2005.

(15) D. Dunn*, S. Graham* and G. Salazar, An Improvement of the Feng-Rao Bound on Minimum Distance, *Finite Fields Appl.* **12**, pp. 313–335, 2006.

(16) V. Lyubashevsky*, C. Newell* and V. Ponomarenko, Geometry of Jump Systems, *Rocky Mountain J. Math.* **35**, pp. 1675–1688, 2005.

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