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Promoting Undergraduate Research in Mathematics**

The Applied Mathematical Sciences Summer Institute

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1. Introduction

AMSSI is an intensive seven-week summer research program in applied mathematics that focuses on diversifying the research experience through the creation of a strong community and the education of the whole person. The topics of AMSSI include the theory and applications of abstract algebra, finite fields, probability, statistics, stochastic processes, and differential equations. In addition, students learn the mathematical software packages of Matlab, Maple, and Mathematica as well as the document processing system LaTeX. These academic tools equip the students for their mathematical research. For their participation, students receive travel to and from Los Angeles, room and board for the duration of the seven-week program, and a stipend. AMSSI, while modeled after successful REUs, has some distinguishing features that help it achieve its goals.

In setting up the structure of AMSSI, we highlight a few of the main objectives of the NSF REU program: expanding student participation in all kinds of research; developing a *diverse*, internationally competitive, and globally-engaged science and engineering workforce; drawing on the integration of research and education *to attract a diversified pool of talented students* into careers in science and engineering; reaching broadly into the student talent pool of our nation to help increase the numbers of women, underrepresented minorities, and persons with disabilities in research; and involving students in research who might not otherwise have the opportunity, particularly those from academic institutions where research programs are limited.

We feel that diversity in every aspect of our society is essential and we use the REU as a way to focus on three underrepresented groups: women, underrepresented minorities, and those that do not have such opportunities in their home institutions. Diversifying the mathematical sciences through the incorporation of these groups has been a top priority for us.

Even though AMSSI 2005 was the first year of the program, its structure has drawn on years of personal and life-changing experiences with similar programs.[1]

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[1]Some aspects of AMSSI were modeled after the REUs MTBI and SIMU. MTBI was founded by Herbert Medina (Loyola Marymount University) and Carlos Castillo-Chavez (Arizona State University) and SIMU was founded by Ivelisse Rubio (University of Puerto Rico, Humacao) and

EC has participated in four distinct parts of the REU—as a student in 1996, as a TA from 1998-2002, as a faculty in 2003, and as a co-director and faculty from 2005-present; SW participated as a TA from 1996-1998, as co-director/summer director from 1999-2003, and as co-director and faculty from 2005-present. The pre-AMSSI experience of both was in the Mathematical and Theoretical Biology Institute (MTBI), now operating out of Arizona State University. Together with Ed Mosteig (2005-2006), Randy Swift (2005-2006), and Mercedes Franco (2006), we guide the students in research and mentor them throughout the program.[2] The collective experiences of the faculty provide a unique perspective on the structure of AMSSI and its goal of diversification.

2. The Academic Structure of AMSSI

From the first day of the program, we stress that AMSSI is a team effort and that helping others learn fosters the building of a learning community from which everyone can benefit. The first week of AMSSI is particularly intense with "math boot camp" lasting from 8 a.m.–12 midnight. We have four hours of interactive lecture and problem sessions in the morning in which the students learn some of the basic material that will form the basis for each of the projects. (This prepares the students for work on their research project, but also gives them common ground from which they can talk with their fellow students about each other's project.) In the afternoon, we have a four-hour interactive computer lab in which students work in different pairs each lab and learn the basics of Matlab, Maple, and Mathematica. During the evenings, the students have a fairly difficult homework assignment. Only by working with each other and with the help of the graduate research associates and faculty can the students finish the assignment in a reasonable amount of time. All the students who have finished voluntarily stay around to help the others. This schedule lasts for the first four days of AMSSI.

At the end of the first week, the students go through a LaTeX tutorial with the graduate research assistants as the faculty meet to break the students into groups of four to begin more focused background lectures for the student research projects. During the second and third weeks, the four research groups will make the transition from classroom theory to independent mathematical research. While the daily schedules of the second through sixth week is not as structured as the first week, the intensity is maintained. A complete written draft of the group's work is due at the end of the sixth week. The students are then given one day of unstructured free time. This "down time" is necessary for the students to re-charge their batteries for the equally intensive seventh week. Each draft is carefully read by two AMSSI faculty and constructive written comments are made on each project. Over the next few days, the students make the relevant changes to their written work and work on their oral and poster presentations. At the end of the seventh week, AMSSI holds two colloquia, one at California State Polytechnic University, Pomona (Cal Poly Pomona) and the other at Loyola Marymount University (LMU), during which time the students give oral presentations of their summer's work. The students submit final copies of all of their work on Friday, thus concluding the academic portion of AMSSI.

Herbert Medina (Loyola Marymount University). Some aspects were modeled from the late Janet Anderson's summer research program at Hope College.

[2]See www.amssi.org for more information on each of the AMSSI faculty.

3. Diversifying the REU Academic Environment

It is clear that strong efforts need to be made to draw from the underrepresented communities (women, underrepresented minorities, and those that might not otherwise have the opportunity) in order to maintain excellence and diversity of ideas. But immersing students in an REU or similarly unfamiliar environment is not enough to guarantee a lasting effect as illustrated by the current data of Ph.D.s awarded in math; see Medina (2004), the February *Notices*, and Peterson (2005). Simply placing such a student in an REU that provides academic/research opportunities but does not attempt to reach out to the individuals' experiences is not an effective way of diversifying. Confrey states that

> "allowing mathematics to continue to require students to disengage from their personal sources of experience and to learn a system of rituals that makes little sense to them but which will admit them to the ranks of the elite is one of the most effective ways of maintaining this oppression" (Confrey, 1995)

in discussing how the oppressive view of abstraction only preserves the status quo.

We address Confrey's concern by exposing our students to activities that cultivate their academic and personal/emotional growth. We "stretch" students by taking them out of their normal element while still providing certain components of familiarity to promote their growth and empowerment. In addressing their personal and emotional growth, we create a strong component of familiarity and community involving fellow students, faculty, and visiting mathematical researchers (both industrial and academic). AMSSI's goal is to develop Ph.D. mathematicians from these underrepresented groups that will impact the culture and diversity of the U.S. while strengthening our communities.

• **Split Campuses:** AMSSI is held for three weeks at Cal Poly Pomona and four weeks at LMU. The schools are approximately 50 miles apart and their locations within the greater Los Angeles area also provides the students with two different academic climates and experiences.[3] We thus build a strong network of support for the students by having the students interact with as many supportive faculty and potential employers as possible.

• **Partnerships with NSF IGERT[4] Programs in the Mathematical Sciences:** As neither Cal Poly Pomona nor LMU have Ph.D. programs, it is essential that our students have sufficient interaction with supportive faculty at Ph.D. granting institutions in order to help facilitate their access to these programs. To help with this, we have arranged partnerships with certain IGERT programs in the mathematical sciences that we feel may be of potential benefit to our students. Various IGERT directors come to AMSSI to give a research colloquia and to distribute information about their respective programs.

• **Recruitment of Students from Non-research/Non-selective Schools:** In order to achieve a diversified group of participants, it is essential to recruit from a very wide pool of talented students. In seeking applicants, we target schools with a large percentage of women and/or underrepresented minorities including all-women colleges, historically black colleges, Native American Tribal Colleges, public universities near large cities (especially in California, Texas, and Florida),

[3]Cal Poly Pomona is a large public school while LMU is a samller private school.

[4]Integrative Graduate Education and Research Traineeship

and community colleges. We use flyers, e-mails, the local newspaper, and especially personal contacts to inform faculty and students about this opportunity. The SACNAS[5] Conference, the joint meetings of the MAA/AMS[6], the Infinite Possibilities Conference, the Andrew Mays Undergraduate Summer Conference, and the Ford Foundation Conference of Fellows serve as excellent forums to recruit a diverse set of students and disseminate information about our program. The students (and faculty) who attend these conferences are not just diverse in their socio-economic and ethnic background but also in their educational interests and field of study. The active participation of the AMSSI faculty in these conferences creates opportunities to talk one-on-one with the students and faculty who can help contribute to AMSSI's sustainability and growth.

The selected dates of AMSSI also play favorably in our recruitment effort. With numerous schools throughout the U.S. on the quarter system, it is essential that REU programs be aware of the potential students that may not be able to apply simply because of the program dates. The AMSSI applications are also reviewed by all the AMSSI faculty, maximizing the potential for choosing a diverse student group and giving the faculty ownership in the program.

• **Exposure to Industrial, Academic, and Non-traditional Applications of Mathematics:** We make the wide-range of career possibilities known to the students. Presentations by the RAND Corporation and Aerospace Corporation, as well as tours of the DreamWorks facilities, the Jet Propulsion Laboratory (JPL), and UCLA Department of Human Genetics gives the students non-traditional applications of mathematics. Besides the non-academic opportunities, we expose the students to more traditional academic career paths and host colloquia by many mathematicians who are known to be great mentors and role models. They each have the opportunity to interact with the students and talk with them frankly about graduate school and Ph.D. programs at their respective institutions. They also talk about the factors, including their personal experiences, that made them pursue a Ph.D. in their respective fields of study.

• **Open Weekly Research Meetings:** Even though the student groups meet and work with their advisors on a daily basis, they also present their work at weekly research meetings to the full AMSSI faculty, the visitors (including colloquium speakers), and campus faculty. These meetings give the students the opportunity to practice their oral presentation skills. Because there are usually first-time visitors present, students give a brief background of their problem and then give an update of current results. Each of these helps the students reinforce what they've learned and better understand their research problem. The meetings also give them an opportunity to think on their feet. Both AMSSI faculty and visitors ask questions (often throughout the presentations) and give feedback to the student groups.

• **Fostering a Collaborative Learning Community:** The positive role of collaborative learning cannot be stressed enough because it teaches the students how to work with others and also builds a sense of community that is essential for success in the summer program and beyond. It is important for the students to understand the type of environment in which they perform best and are happiest.

[5]Society for the Advancement of Chicanos and Native Americans in Science (`www.sacnas.org`).

[6]American Mathematical Society (`www.ams.org`) and Mathematical Association of America (`www.maa.org`).

To help provide students with information about graduate school we have designed a comprehensive and thorough four-hour interactive session led by an expert on the graduate school application process. Supportive fellow students, faculty, and visitors also provide encouragement to pursue higher degrees.

Because we focus on the recruitment of students who might not otherwise have the opportunity to conduct research, we believe that there must also be a concerted effort to use all of these academic tools in the greater context of overall student growth. Confrey's 1995 research suggests that many of our students would typically have no choice but to "disengage from their personal experiences" in their efforts to pursue their goals of attaining a higher degree. This in turn will have detrimental effects in their learning capacity. Recognizing this possibility, from the beginning we try to ensure that the AMSSI experience for our students is one in which their emotional growth parallels their academic growth. We agree that

> "the introduction of emotional intelligence into discussions of mathematics education allows one to assert that both facilitating and debilitating emotions play a significant role in learning, and that emotional qualities of classroom interactions will exert a significant influence on what is learned" (Confrey, 1995).

A key step in the direction of incorporating the emotional growth in the AMSSI experience is the weekly sharing meetings, which are attended by student participants and the AMSSI faculty. In these meetings, each member shares some of their personal side, including significant life experiences, dreams, fears, obstacles they have overcome, upbringing, family background, role models, hobbies, etc. Only AMSSI students and faculty attend the meetings to maintain a culture of confidentiality, trust, and respect that we carefully build throughout the program. These meetings establish a non-academic connection between the students that carries over into their work, as they now have a better understanding of each other from a non-academic perspective. The meetings also foster a very strong bond between students and faculty that further establishes a sense of community and creates a solid mentoring relationship. By the end of the program, everyone has had the opportunity to ask questions, have questions asked of them, and share a personal side of them that otherwise would not have been possible to share outside of this setting. The emotional intensity of the weekly sharing meetings complements the intensity we require for the academic aspects of AMSSI. Both students and faculty also participate in a weekly extracurricular activity.[7]

4. Preliminary Results

Even though AMSSI 2005 was the first year of our program under this REU model, we have had many successes. The eight manuscripts from 2005-2006 were compiled into a bound Technical Report volume; see `www.amssi.org`. The students also gave poster presentations at the SACNAS conference and at the joint meetings of the AMS/MAA. At the latter conference, two of the groups won poster awards for their work. Multiple students also presented their research at their home institutions and local undergraduate conferences. One of the posters also won an

[7]A large percentage of AMSSI's targeted students come from low-socioeconomic backgrounds and thus we do not require them to pay for mandatory activities; funds to cover the students in any mandatory extracurricular activities come from the generosity Cal Poly Pomona's Dean of the College of Science, Donald Straney, who recognizes the importance of a complete REU experience.

award at the SIAM[8] Southeast Atlantic Section Annual Meeting and again at the MGE@MSA/WAESO[9] Conference. One student presented his group's work at the 2006 Joint Meetings AMS Session on Probability and Stochastic Processes (#262, "Birth-Death Processes with Polynomial Transition Rates"). The manuscript entitled "Alcohol's Effect on Neuron Firing" was accepted for publication to the refereed journal *The Mathematical Scientist* and is scheduled to appear in vol. 32, no. 1, June 2007. The paper entitled "On the Representation of Birth-Death Processes with Polynomial Transition Rates" has been accepted for publication to the refereed *Journal of Statistical Theory and Practice*. We anticipate similar dissemination and success of the work of AMSSI 2006.

A key to AMSSI's success is the dedication of its faculty. As mentioned earlier, a sense of ownership in the program is fostered from the beginning, which is essential for success in this time-intensive environment of learning and mentoring. Educating and mentoring the whole person includes sharing life experiences, listening, strengthening self-worth, connecting emotions and familiarity to new knowledge, fostering individual growth, building trust, creating a strong community, and making work a team effort and experience where everyone contributes and benefits.

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[8]Society for Industrial and Applied Mathematics

[9]More Graduate Education at Mountain States Alliance (MGE@MSA)/Western Alliance to Expand Student Opportunities