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

# Notes on PURM Conference

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## 1. Welcome

### 1.1. Jim Schatz, NSA.

- The NSA is the largest employer of mathematicians in the country. Mathematics has long been useful to the intelligence community and has been a huge success story for it. The NSA needs a healthy mathematics community and thus is interested in the state of math in the US and not just short term recruiting to the NSA. Part of a strong community requires encouraging diversity.
- We should be open to all kinds of mathematics, and not look down upon applied mathematics, which can also be very elegant. We shouldn't limit ourselves.

### 1.2. John Ewing, AMS.

- Some advice graduate students give to undergraduates: math research is hard so make sure you really want to do it. REUs are important to help students figure out what they want to do.
- Goal of conference is to understand different types of undergraduate research programs.

## 2. Opening Address

### 2.1. Joe Gallian: Undergraduate Research 1987-2006.

1986 MAA president said, "Undergraduates can neither participate in nor understand the research of math professors." While this may be true, we can take a better attitude.

1987 NSF starts funding REUs, with expectations of students doing examples, generating data, or doing a literature search. This is now what happens in the first week of an REU! There were 8 REUs, mostly 4-6 weeks, and there was nothing at the Joint Meetings related to undergrad research.

1988 MAA formed an Undergraduate Research Committee (which has been a big influence on undergraduate research). There were 14 REUs.

1989 16 REUs.

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1990 The NSA starts the Director's Summer Program. AWM starts the Schafer Prize. 15 REUs.

1991 MAA committee gets poster session at Joint Meetings for undergrads, and also a panel on undergrad research, and a three part special session for research papers by undergraduates (22 talks representing 54 students).

1994 At the Joint Meetings: First MAA minicourse on undergraduate research, and the second MAA poster session for undergrad research (and made an annual event–though starting with small numbers, recently the poster sessions involves hundreds of students and is limited by the room size), and the AMS had another special session for undergrad research (38 talks, 70 students).

1995 The AMS has another special session at the Joint Meetings for undergrad research. Aparna Higgins gives the first Project NExT course on undergrad research. The Morgan Prize is established.

1996 Undergrads speaking at the Joint Meetings are identified in the program. There are 6.

1997 MAA minicourse on undergrad research at Joint Meetings.

1998 Now 171 undergraduates at the Joint Meetings, and 36 doing posters. At the Joint Meetings, there was an MAA session for faculty about undergrad research.

1999 First PURM conference, predecessor to this conference.

2001 MAA adds "undergraduate research" to their mission statement.

2002-6 At the Joint Meetings, things like special sessions for undergrad research and minicourse become annual. 49 REUs, 377 undergrads at JM, 192 students in poster session at JM.

- People with NSF grants can get supplements for undergrads to do research.
- Michael Dorff got an NSF grant to fund academic year undergrad research at various schools.
- FOCUS will have a column with good undergraduate research problems.
- In the right circumstances undergraduates can do mathematics research.
- Reasons for changes: NSF and NSA funding, popularity of REUs, DSP program at NSA, minicourses, VIGRE, CUR (Council for Undergraduate Research) played a big role behind the scenes, people who were in REUs now running their own, more pressure on faculty to do research.

### 2.2. Aparna Higgins: Undergraduate Research at your own institution.

- REU research is great, but there are benefits of non-REU research done during the year.
- Consider: is a measure of success of these programs how many students go onto graduate school? While REUs may help in this regard, so could in-house research. Maybe REUs just confirm people's interest in grad school?
- Ways to do undergrad research: REUs, honors or scholars programs, senior projects, and one-on-one work with faculty
- Reasons to work with undergrads: introduce them to profession, advance mathematics. These goals are not mutually exclusive.

- Advantages of in-house research: introduces students to profession, it is fine if results are not publishable "The only person that an undergraduate research problem needs to be important to is the student." The experience is valuable, whether the student goes to grad school or into the workforce. More benefits: more time than REU, students can learn more broadly, easier to find a doable challenge, time to tailor the project to the student, no funding required.
- Research experience for undergrads is a pedagogical exercise. Discovery learning is a trend in education. The skills that come out of this are good for people who go into math, people who become teachers, and people who go into industry where they need problem solving skills.
- Let's find out lots of ways to do undergrad research!

## 3. Panel: The Spectrum of Undergraduate Research Programs

*Panelists described current forms of various undergraduate research programs: NSF-funded REUs, other summer undergraduate research programs, minority-serving programs, and academic year undergraduate research programs.*

**3.1. Erika Camacho, Loyola Marymount University.** Runs the Applied Math and Science Summer Institute for minorities. It is important to recruit minorities to have a diverse workforce and give research opportunities to students who wouldn't otherwise have them (as per NSF guidelines). In 2000, 14% of Bachelor's degrees are from minorities; from 1997-2004, 5.7% of PhDs were minorities, and 31.3% were women. We need to not only introduce students to the academic environment of mathematics, but also provide them a good personal and emotional environment to make them comfortable, build their self esteem, show them role models not just in academia (also PhDs in industry). AMSSI unique features: held at two campuses (one and then the other) in a summer–faculty are resident and move also, they recruit from schools without strong math programs, they set dates to accommodate quarter systems, look for potential in students not just good past work. They have weekly group meetings where everyone (including faculty) share their worries, goals, family background, etc. They have a first week math boot camp, 7 days from 8AM to midnight. To encourage self esteem: pick students randomly from groups to present and then give a lot of positive feedback, make them work hard so a lot is accomplished.

**3.2. Zsuzsanna Szaniszlo, Valparaiso University.** Valparaiso does academic year research as well as having an REU. Math majors are required to take a colloquium every year (no credit first three years, 1 credit hour one senior semester) which meets once a week for an hour and each year has different goals. In the year long projects, they put together younger and older students, and find seniors are often too busy to participate. The goal is a good research experience, not necessarily publication. The project work is divided up some by experience and age: younger students produce examples and counterexamples, middle students produce conjectures, and the older students produce proofs. Every week each student has their own task for the week ahead. Recently, faculty get some teaching credit for participating. Students usually don't participate for four years, maybe freshman year and then again junior year. They recruit by personal contacts.

**3.3. Suzanne Weekes, Worcester Polytechnic Institute.** At WPI, research is integrated into the curriculum and there is a collaborative atmosphere. They also have an REU, which has involved 200 students, 60 industrial projects, and 30 companies. The motivation is applications to real world and to society, and the problems come from industry partners. They work on communication and working with a diverse team. They have good percentages of women and students not at PhD institutions, but have trouble with minority recruitment. One goal is showing the role of math and industry and working with constraints. Students' interest particularly in their REU is important in the application. They do a phone interview/information exchange. Students are in teams of 2-5 students, meeting with faculty at least once a day. The final reports are to the companies and thus usually not allowed to be published.

**3.4. Peter May, University of Chicago.** At Chicago 7-8%, of students are undergraduate math majors. Seventy students participate in their REU, closed to seniors because of lack of space (28 grad mentors, 11 faculty mentors). The students take courses and do projects, and also teach high school students or grade school teachers. During the 8 week program, there is a 4 week program for high school students, and a 2 week program for local grade school teachers. The program is very popular and they get more applications than they can take. The goal is not to publish but to get students excited about math. The math only needs to be new to the student. Chicago also has a directed reading program run entirely by graduate students, where they meet one hour a week. Grad students are paid a nominal $300.

## 4. Small Group Reports: Overcoming Challenges[1]

*Participants broke up into 6 small groups, each with a facilitator. In each group, the participants discussed challenges they have faced in their undergraduate research activities, and how they have overcome these challenges.*

- How to get undergrads to help your research instead of hindering it? Get them started earlier so they are around for longer and can mentor younger students. They can do examples on computers, with examples of success both in PDEs and in number theory.
- How to deal with director burnout? It is hard to keep finding problems! FOCUS is going to print a column with suggested problems, but it would be bad if lots of groups started working on the same one and competing. There should be a wiki webpage, clearly given in the column, where people can say what they are working on and what results they have on these problems. Try getting problems by going to specialized conferences outside of your area and asking simple questions.
- NSF REU mentors are not paid enough compared the pay for standard NSF research grants. People on NSF review panels shouldn't look down on applications asking for faculty support. You can have support staff or undergrads do some of the administrative work to take the burden off faculty.
- How to keep a program going? Get more professors involved. Have the head of the REU doing minimal mentoring. Pick a faculty successor to

[1]Jeffrey Adler contributed to this section.

the director. To get more funding, you could ask alums of the university (sometimes you need to go through the Development office). Another idea–Howard Hughes Medical Institute supports summer research for undergraduates. NSF research grants in the department can help a student or two. If you can't get teaching credit, at least get recognition from the deans. The NSA has some start-up funds, but not continuing funds.

- Get the CUPM document on costs and benefits of undergraduate research programs. It is written to convince administrators. It is available at: `www.maa.org/cupm/CUPM-UG-research.pdf`. It is very important to make sure that the administration knows what we're doing. This came through loud and clear.
- To run undergrad research at a PhD institution, you need external funding, smaller schools don't expect much funding (faculty are more expected to do it as part of their job). Make the university aware of the work you are doing.
- How large should groups be? A lot of people think two students is good. Maybe with three, someone gets left out.
- What happens when students fail to show up at the REU? Or accept and then later turn it down?
- What do you do with unfinished projects? Should you reuse them?
- How to improve communication ability of students? Practicing their talks helps a lot, and instills a value that it is important to give good talks.
- How to get support for academic year research with students? Don't be afraid to use buzzwords. Get on university committees. Toot your own horn.
- What to do the summer between undergrad and grad school? (There is a bridge program at University of Nebraska-Lincoln.) The focus would be different. Instead of promoting graduate study, we are preparing them for graduate study.
- Are women only programs good? They have positives: strength in numbers, good role models.
- Do phone interviews help? Maybe you can weed out students with bad attitudes but some good students don't interview well on the phone.
- Jim Schatz from the NSA says *the NSA can provide a letter explaining the importance of undergraduate research from their perspective.*
- How do we prevent fighting between REU directors over students?
- NSF has a program to fund REUs for U.S. citizens to do research in other countries. Some people hope for funding for non-U.S. citizens in NSF REUs.

## 5. Panel: Diversity Issues in Undergraduate Research

*The panelists in this session discussed the importance of involving minority communities in undergraduate research in mathematics in order to increase their representation in the area. They also discussed effective recruiting techniques and successful strategies.*

**5.1. Herbert Medina, Loyola Marymount University.** 54.9% of PhDs in math in the US are to US citizens or permanent residents (46.2% just to US citizens). These have been decreasing over the last 10 years. 28% of math PhDs

are women, 6.2% are black, Hispanic or Native American. US citizens are more likely than non-citizens to take initial jobs in the US. There is a downward trend in math BAs, both among all college degrees, and the percentage that are US citizens. One way to combat these issues is to tap into the resources of the underrepresented groups that may not have the tradition of grad school in their culture and have pressure to get a job immediately, and the mathematics programs aren't working well to develop this talent. Undergrad math degrees to blacks, Hispanics, and Native Americans are on the rise (despite the decline overall), so this is a good resource to focus on.

**5.2. Darren Narayan, Rochester Institute of Technology.** Narayan ran an NREUP program. His goal is to get more underrepresented groups into PhD programs. NREUPs run 6 weeks typically, with 4 students and 1 mentor ($5000 to program director and $3000 to each student), the students must be *named in the proposal*. The problem used was good because it was easy to describe to others and had applications. Students cooperated to built up examples and the whole team counted down on finitely many cases left to resolve, which was exciting and motivating.

**5.3. Ricardo Cortez, Tulane University.** Challenges are students with low income and no family or friends who went to grad school or even college. The strategy is to aim for students after their sophomore or junior year, do a research program, and then do a lot of work following-up with them. Talk to them about graduate school and fellowships, make them part of a larger network of mentors and get them tied into the community. For this, groups of three are best. Set the right tone and atmosphere for cooperative learning. Also, it has been good to start with a lot of structure to the program and then reduce it slowly giving students more freedom and responsibility. It is great if students end up working 15 hour days, by their choice. Lead by example and really be there for the students. The program avoids accepting students already on a fast-track to grad school.

**5.4. Dennis Davenport, Miami University.** To generate applications: go to conferences with minority students, advertise at national and regional conferences, do mass emailings but pick specific people who care about what you do and not just department chairs, contact institutions that graduate lots of minorities (see www.diverseeducation.com/index.asp), and have a good website. Students who apply without a proof based course aren't ready for the REU but they need to be recruited early into mathematics, so we need some kind of pre-REU program to reach out to these students. The top minority students get a lot of offers, but there are still minority students with a lot of potential we can reach out to. Calling people with many offers has been successful to recruit them.

**5.5. More comments.**

- To recruit minority students, it will take time and effort over years. Use the contacts from this conference to help!
- To try to recruit more low income students, we could ask for more information about this on applications; for example asking students to talk about their background, or asking specifically if they are first generation college.

- Is it better to have minorities in all minority programs or ones with a critical mass, or is it better to spread them out? We need to be finding new students, not competing over the ones we already know about. Look for talented non-math majors.
- When "taking a risk" on a student with less background but perhaps potential, you can call people who wrote letters of recommendation to learn more about the student before deciding to make an offer.
- Pairing weak students with weak students is better for the students than weak with strong.

## 6. Open Forum

### 6.1. Faculty Compensation for REUs.

- Almost everyone present has directed an REU, but almost none had local compensation. Someone wrote *local* support into their grant (e.g., 15% locally and 85% from NSF for compensation, in trade they took $\frac{1}{3}$ of their students from the local university). Some schools already have programs in place for local students to do summer research, and the REU can be tied in with this.
- At one place, students were enrolled in "summer classes" as extension students, the grant paid the tuition, and then the mentors were paid by the school as teachers.
- Should we ask for more from the NSF? (Yes, is the consensus.) It is more work than doing your own research, but yet you would get paid more to do your own research. Some people have successfully written in two months of support into their REU grant. Someone on a grant panel pointed out that review panels will notice if you ask for more support, so you should explain why.

### 6.2. Have REUs caused the quality of entering grad students to improve?

- Some people have noticed the quality of entering grad students improving.
- More students are now going to REUs since there are more REUs. REU applications are getting better, at least anecdotally. This should be documented.
- Someone says grad students who had been to REUs had an easier time in grad school. Can this be documented? Someone else says REU alums have a harder time because PhD problems take longer and more background.
- Lacking a recommendation from an REU director (whose REU you attended) is a red flag on a student's grad school application.
- When an REU director is writing a recommendation, it should concentrate on the student, not the REU. It shouldn't say too much about the REU, and should speak first about the student, mentioning the REU only at the end.

### 6.3. What is the right size group for students at an REU?.

- Students can work alone on related problems and then discuss them a lot. It is important to still develop communication skills even if students are working alone.

- It is good we have many models that work for different students, e.g. group and individual work.

**6.4. Adding undergraduate research to the curriculum.**

- If we add undergraduate research to the curriculum, how can we justify it (and what will be cut out) to other faculty? You could just add research without cutting anything, making the program harder for students. You could try to incorporate research projects into the regular classes, but that will necessarily reduce course content. Maybe if students are going into industry, a research project would be more useful than some of the standard curriculum.
- Some state schools have a revenue generation model for deciding what gets taught. This is bad for undergraduate research.

**6.5. Are the numbers of Master's degrees in math going down, as the PhDs are?** Is this important? Should we consider the mathematics community we would like our students to join to only include PhDs, or Master's also? Yes, we care about the students with Master's. The NSA likes REU students even if they don't have PhDs.

**6.6. How do we define undergraduate research?** A student has to produce something credible *to the student*. Students get "beat up" in math classes, in research they come up with new answers together. The MAA Committee on undergraduate research has a document defining this, which is now available online.

**6.7. If an REU student becomes a high school teacher...** it is great! They can teach with that perspective.

**6.8. What can you do with half finished projects?** One student later used them while he was tenure track (i.e. students can finish them later on their own). The mentor can finish them. The REU mentor could find a professor at the student's school to help the student finish the project.

**6.9. Where do we get models for undergraduate research?** We should try looking at other sciences and adapting their models.

**6.10. Announcements.**

- Michael Dorff at Brigham Young has a $1.28 million NSF grant to give out mini-grants to do in-house research. They buy out a faculty course for $5000 and give $3000 to the student. email: `mdorff@math.byu.edu`
- July 16-19 there will be a NSA sponsored conference in Duluth Minnesota with colloquium style talks.

## 7. Panel: Assessment of Programs

*The speakers summarized information gleaned from assessments now available to determine the impact that research programs have had on students. The assessment techniques that some REUs now use were presented.*

**7.1. Michelle Wagner, NSA.** NSA funds 14 REUs, with a strong minority focus (8 of the 14 have significant minority participation). To assess, the NSA does site visits and performance reports. They want to see objectives achieved and summaries of student projects. The site visits also help develop relationships with students and faculty.

The NSA did a survey asking REU directors for information on previous students from 1988-2005: where are they now, what degrees did they get, what jobs are they in. (Note: this does not include DSP.) The data has a lot of missing points, and some students appear twice. The data show 59% female and 41% male, though if you take out the two women only programs it is 49% female and 51% male. They are very balanced racially, including 26% Hispanic/Latino, which a few programs are responsible for. The graduate school data is 45% unknown and 35% have gone to grad school in math. Of the 527 in math or statistics graduate school, 183 are minorities and 187 are women (a drop from the REU participation). In the future, the NSA would like to get more and better data, and get more underrepresented groups in REUs.

Question: How can REU directors keep track of students? Answers: email, Google, forced exit surveys, yearly questionnaires, ask other students. You can ask the NSA for administrative assistant funding to do this and other administrative work in your grant.

Comment: one reason it is harder to track female REU students is some of them change their names.

**7.2. Frank Connolly, University of Notre Dame.** The AMS did a survey of 411 REU students from 1997-2001, with 262 responses. The respondents were 55% male and 44% female, 9% Latino/Hispanic and 2% African-American. Of the 262 respondents, 75% did an REU not at their home institution; 36% did an REU with a strong instruction component and 61% went to an REU solely focused on research. Student opinion: 84% said it was valuable, 16% said somewhat or not valuable (100% of Latinos said it was valuable); 83% said it did not shorten their time to a PhD. Did it accelerate their development as mathematicians?: 22% said definitely, 68% of Latinos said definitely, 44% said slightly, 23% said no. 53% of students said it had no influence on their choice of thesis topic, 36% said it had a slight or definite effect. Was the REU a factor in going to graduate school (for those who did)?: 78% said definitely or somewhat, 82% of women and 90% of Latinos said definitely or somewhat. Did an REU get you into a better graduate program?: 76% said definitely or somewhat. Did it help you win a fellowship? (the question didn't make it clear what to do if you didn't get a fellowship, or if a teaching assistantship was a fellowship): 48% said yes, (79% of Latinos), 24% said no, 28% no fellowship/can't answer. Of the 262 replies, 72% went to PhD programs and 13% went to Master's program, with 66% in math and 30% in other mathematical sciences.

A question to ask next time: did the REU increase your commitment to mathematics?

There were lots of positive comments on the survey by the students, and 5 negative comments.

**7.3. Dan Isaksen, Wayne State University.** When assessing our programs, we all look for future math achievement. What else should we look for?

Different programs have different goals. Here are some examples to consider. Example 1: After attending an REU, a student decides she doesn't want to do math and goes to electrical engineering graduate school. Example 2: Because of a good recommendation from an REU director, a student gets into a difficult PhD program and leaves with a Master's. Example 3: A woman is having good success in a PhD program with a few publications, but she puts her career on hold to start a family. Example 4: A student does not have a mathematically successful REU experience but has fun, and goes on to become a tenured math professor. Example 5: A student is an REU purely to pad his resume and goes to law school as previously planned. Example 6: A student's REU problem turns out to be previously solved, but the student later becomes a math professor. Success or failure? Some points of success for REUs are better networking, helping students make better career decisions (even possibly to leave mathematics) and developing professional communication skills.

Audience comments and questions:

- There may be a disconnect between goals that are good and the goals that the NSF has for REUs. One challenge is how to measure our goals.
- Should the quality of research produced by a student be a measure of REU success?
- One way to assess (according to the NSF) is whether the program transformed a dependent student into an independent student.
- Howard Hughes Medical Institute invites programs to participate in their survey. Contact David Lopatto at Grinnell College about SURE II survey.
- Do grad schools like REU experience? Many schools see it as a positive. When students work in teams, it is hard to tell what individual students contributed. Students should write about their REU research, explaining how it fits into other mathematics (e.g., what other mathematics is related to the work that they did). The recommendation letter from the REU director is very important, and its absence is a problem.
- One concern is that REUs give students a "too easy" impression of what math research is like.

**7.4. Websites to look at.** Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering
`http://www.nap.edu/catalog/11741.html`

National Academies Committee on Women in Academic Science and Engineering `http://www7.nationalacademies.org/womeninacademe/`

## 8. Panel: Perspectives from Students

*Current graduate students described their undergraduate research experiences and the impact these have had on their mathematical development. They also discussed the way their time in an undergraduate research program affected their graduate experiences.*

**8.1. David Uminsky, Boston University.** David's first REU was at the SIMU program at Puerto Rico in 2000.

- How did he choose SIMU? He saw a poster by chance in the hallway. It was the only REU he applied to.

- Did the REU affect his graduate school decision? Yes. He switched to being a math major after the REU because he saw a glimpse of life as a mathematician.
- The mathematical content of the research did not matter as much as the experience, but he is still working on a project that grew out of what he did at the REU.
- Did an REU better prepare him for graduate school? Yes. The tangible benefits were how to write in LaTeX, Maple and Mathematica skills, mathematical speaking skills. He got a chance to go through the refereeing process and it built confidence. It helped him get into graduate school.

**8.2. Melanie Matchett Wood, Princeton University.** Melanie did the Duluth REU in 2000 and also did academic year research at her undergrad institution, Duke. Her research experience was a big part of her decision to go to math graduate school. It showed her the most exciting part of mathematics and gave her confidence she could do math research. She applied to seven graduate schools, and ended up going to the school she least expected to attend, in a large part due to two contacts she had made through her research experiences. The REUs helped her prepare for graduate school by helping her develop research skills. She loves communicating about mathematics, and the lack of it she finds problematic. In both of her research experiences she worked alone. One big positive effect of REUs is students getting in touch with experts in a field, and it is good to have feedback from a professional in the exact area. At Duke, her adviser was in a related field, but she was put in touch with experts in the field and that helped a lot. Her experience is unique because she only likes certain parts of mathematics, so it was very helpful that she was able to choose problems she really liked in her research experience.

**8.3. Paul Gibson, Northwestern University.** Paul was an undergraduate at Notre Dame. Notre Dame had an honors math track, which he felt was very important in his development. His first summer of college he was a lifeguard. In the following year he did more math and the honors track math adviser suggested that he participate in the Notre Dame REU. The Notre Dame REU was a lot of fun working in a group. He met an adviser every day for two hours. His junior year, while abroad, he stayed in contact with the math department, keeping him on track for graduate school. That summer he went to an REU at Indiana University, with a mini-course (not tied to the research) and a project he worked on alone. He met with an adviser once a day. He liked both the group work and working alone. In his senior year, he participated in a seminar on undergraduate research at Notre Dame, which was a reading course in Riemannian geometry, his current field in graduate school. He went to Northwestern because it was a good school and he got lucky there were a lot of professors there doing what he likes.

**8.4. Rana Mikkelson, Iowa State University.** She went to Kalamazoo for undergrad, and she didn't like linear algebra, but it is now her research area. She attended the 2002 Grand Valley State REU, where she studied dynamical systems, and is now a mentor at the Iowa State REU. At her REU there were a lot of good social activities with other students, including a daily group breakfast, and official and unofficial activities, for example Xbox in the math building. It was a good way to meet professors in a nonacademic context, which makes it easier to

talk to professors about academic things. Her research partner at the REU was older and more experienced so it was important she felt comfortable talking to a professor. The group work was successful because the pair complemented each other: her partner had lots of big ideas and she worked on the rigorous details. The students and mentors found problems to work on together by looking at examples for patterns. It was a great way to spend the summer instead of just taking more courses. It confirmed she shouldn't be afraid of doing math research. She learned LaTeX and math writing skills, had practice giving talks and heard a lot of good talks. She went to an REU at the suggestion of a professor and from looking at a poster. Her other research experience was her senior thesis, which was a bad experience because the question she was working on had a false assumption. This was exacerbated by the fact that the problem was outside her adviser's specialty, but even so she learned from the bad experience. She attended the Nebraska Undergraduate Conference for Women, which was a great experience.

### 8.5. Questions from the Audience.

- How do you keep students happy at an REU? Do students miss the freedom of a car? It was great to have fun weekend activities. Living and cooking with other students was a good experience. Having rented cars sometimes available helps. Students can find fun things to do on their own. Students can join university activities, like intramural sports.
- Given that math is different from experimental sciences, how did an REU help with your courses, and could REUs be different to help you more with coursework? REUs help develop good work habits. They might make students want to know more how courses are relevant to other mathematics. The REUs show you the light of research at the end of the tunnel of courses. REUs address different topics from coursework.
- Could an REU experience help borderline students to graduate school? Most students in a grad program had done research as undergrads. People who are double majors could benefit from an REU experience, but most REUs focus on people just doing math. REUs would be good for non-honors track students or students who wouldn't otherwise have research experiences. It is good to check up on students after the summer.
- How could we measure value added of REU programs? You could give before and after surveys, but make surveys anonymous.
- What is your family background? DU: Mother Spanish teacher, father eye doctor. His high school was not so great, and his Dad wanted him to major in physics and be a doctor. MMW: Mom is a public school teacher, and was 100% supportive of school and graduate school. PG: Father is an engineer and mother a lab assistant. His high school wasn't good. RM: Father a farmer and switched to construction, mother in corrections, and neither went to college.
- Poll to the audience: How many of your programs could help borderline students (i.e. students who aren't sure of their interest in mathematics)? Lots of hands went up. How many of your programs advertise this? Few hands.
- What to tell students who don't get into REUs? Help them connect with local professors to do research.

- Was money a factor in your decision to go to an REU? Not at all. A little bit. It helped decide between REUs. It was important that the REU didn't cost anything to the student.
- Do students expect to get a paper published from an REU? Not for me. In some competitive grad schools, most students have undergraduate research papers. A submission is not so important but writing something up was good. I didn't expect a paper but I did ended up submitting one. The students' impression is that grad schools look favorably on papers.
- There is a concern about the feeling that research papers help students get into graduate school. The NSF graduate fellowship application supports this by asking students for a research plan.

## 9. Reports from Parallel Sessions

**9.1. Uniform Acceptance Date.** It is good for transparency but there are numerous problems. Mainly, students will know if they are second or third choices for an REU. This might affect their interactions at the REU. A big question we need to know the answer to: How many students apply to REUs and do not get in any program?

Moderator asks: Could we agree to a date before which students would not be required to accept an REU offer? We need to make sure we can still be competitive with offers from industry internships. Some people want to make their acceptance dates later. There is a lot of confusion between uniform offer dates and uniform acceptance dates, and also between these and a date *before which* no student could be asked to respond. The graduate school acceptance model seems to work well. No one objects to agreeing that students should not have to respond to offers before February 20.

**9.2. Generating Research Problems.** Good things in a research problem: in the adviser's area, a careful literature search is part of the research, the adviser should have ideas for the first few steps, the problem should be easy to get into, students should learn some new math, the results should "in theory" be publishable. It is good to help students connect with a field of mathematics. The problem should be open ended. One concern is that the student makes a small advance, but then the problem is solved entirely by a professional. One solution is to tell the students it is okay if they can't publish their results. Being able to do computations is great. It is good if advisers at least guide students in selecting problems.

**9.3. Undergraduate biology and mathematics programs.** Some students want to see the relevance of their research, and working in mathematical biology is a good way to do this. Graduate school requirements for mathematical biology are different from pure mathematics and so the definition of success of these programs must be different: students going to any graduate school is good, not just math graduate school.

**9.4. Working with Local Students.** Usually it is not part of an REU, but when it is part of an REU it is important to make sure students are full participants in the REU and live with the rest of the group. It is important to give students problems that are good for *them*. If students are working on a non-publishable problem, should it be called research? Know your audience: yes to the deans, tell

colleagues it is an independent investigation. Can we bridge the gap between an REU and the classroom? We could have a project or investigation in class.

**9.5. Using graduate students as advisers.** They are likely to be committed to the program and they can do lots of work. How to pay them? Maybe the department can, or you can put it in the grant. What can they do? They can teach LaTeX, they can make mathematical suggestions, they can design the t-shirt, and they can plan social activities. The grad students are closer to the students and so they can find issues with students and group work and report it sooner to the director. How to make sure the graduate students are working? It is not an issue if you pick students you know are hard working.

**9.6. Helping undergraduate students into graduate school.** What if students have low subject GREs? Look to see if the schools they are applying to require the subject test and if they have a strict cutoff. A poor verbal GRE is viewed as a negative. A letter of recommendation from past REU directors is critical. Letters should be no more than two pages, and should talk about the student at the beginning, with information on the program or details of the research as an appendix. Instead of getting students into the best school, you should get them into the right school.

## 10. Closing Panel

Joe Gallian "Good things happen when people get together." He learned a lot about REUs during this conference. Mark your calendars for the next PURM conference in 2012!

Frank Connolly said the value added to REUs is developing a student's career, showing that math can be fun, developing their confidence in research, and increasing their commitment to mathematics. He feels that $6000-$6500 per student is not enough funding for REUs. We should look into levels of funding of REUs in other disciplines. While there are lots of definitions of success, the NSF and NSA definitions matter, since they are funding the programs. Colleagues don't always recognize the importance of undergraduate research.

Ivelisse Rubio said the expectation of this conference was to exchange ideas and that has been a success. It is great that many people are increasingly aware of the issue of getting underrepresented groups into research and REUs. Summer research is great, but we can also work on more academic year research.

Aparna Higgins said the highlights of the conference were meeting research directors, and learning about the diversity of research experiences. We can't just have one model. She is delighted to hear people trading suggestions about issues with research programs, and to hear people talking about year-round research programs. She would like to see more programs for people who haven't had as much preparation. She was disappointed by the focus on REUs since not all students can go to REUs. Contact Michael Dorff (`mdorff@math.byu.edu`) for more information about mini-grants for year-round research.

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