Newsletter

Mathematicians and Education Reform ...Forum...

Fall 2002 Volume 15 Number 1

Undergraduate mathematics majors: We need more of them

by William Yslas Vélez, University of Arizona

Editor's Note: The following article is the second part of a two-part article. The first part appeared in the Spring, 2002 issue of the MER Newsletter.

Précis of Part 1

With the goal of increasing the number of mathematics majors, readers were challenged to confront the question of whether mathematics departments function primarily as service departments or as professional schools, as engineering departments do, for example. Mathematics faculty were advised on practical ways to counsel students to think of being a math major as preparing for a career as a professional mathematician.

Now that we have decided that there is a need and a desire to increase the number of mathematics majors, we should also ask: why would a student choose to major in mathematics? I am embarrassed to say that this is not a question that I have asked the many mathematics majors that I have known over the years. I can give my impressions as to why some of the students have chosen this major.

1. There are students who have chosen mathematics for the same reason that we have. It was interesting.
2. The student has planned to be a high school mathematics teacher.
3. The student started in engineering or some other science major and the material was not to his/her liking. This major required mathematics and since the student has already taken some mathematics, a major in mathematics is a possibility. Furthermore, mathematics is viewed as a technical degree with more job prospects than a non-technical degree.
4. The student met a mathematics professor who was inspiring.
5. Since mathematics is a liberal arts degree, the student has more freedom in selecting a course of study, while still selecting a technical major.
6. Mathematics keeps one's options open. An undergraduate degree in mathematics, together with a supporting minor, can gain entrance to a graduate degree program or a professional degree program (law, medicine, MBA).
7. Mathematics is often viewed as a hard subject. There is a sense of pride in being a mathematics major.

It would be helpful to better understand the reasons why students choose mathematics for their major to aid us in developing programs that would increase the number of mathematics majors.

The many benefits to increasing the number of majors in a department include: Large numbers of majors give a sense of vitality to an undergraduate program. Advanced courses are well populated, making it easier to run the advanced courses. Having lots of students in advanced classes makes it more comfortable for those students. There are peers with whom to discuss problem sets. It makes for a more lively class. The university administration will also take notice of this increased activity and increased resources will be allocated to the department.

There are also some monetary gains that will eventually come to the department. Periodically we hear about someone who has contributed large sums of money to a

continued on page 11

inside

from the editor

At the recent November workshop on Excellence in Undergraduate Mathematics: Diversification of Upper-level Mathematics Programs at Louisiana State University, the introduction to the workshop program included a checklist for departments based on lessons gleaned from the first two workshops:

Things to keep in mind

- Diversification of the curriculum
- Effective instructional approaches
- Communication with other disciplines
- Communication with professional users of mathematics
- Quality of life for students in the math department
- Appropriate uses of technology.

This issue's articles on *Undergraduate mathematics majors: We need more of them* by William Vélez and *Upper-level Math Courses for Math Outsiders* by Stephanie Frank Singer have relevance to the "quality of life" issue and the issues of "diversification of the curriculum" and "communication with other disciplines," respectively. Vélez continues to argue for mathematics faculty to pay attention to their students. This plays out in several ways, but especially in being an enthusiastic advocate of mathematics in the classroom and on a one-to-one basis with students. While focusing on the calculus class as a recruitment opportunity, he describes a proactive program of building interest in mathematics with exposure to mathematics current events, identifying and encouraging promising students, and helping them make connections between academic studies and preparing for a career.

Singer has taken the path to explore new territory in developing undergraduate courses on applications of algebra and analysis to physics. She notes that the first step in her project was to immerse herself in the "language and culture of physics," and describes how she had to adjust to physicists' vocabulary and interpret what she heard back to the context of mathematicians. One senses that her colleagues in physics were very happy to talk about their work, on and in their own terms, to an interested, appreciative listener. The courses seem to work on several levels: first, they draw students from physics and chemistry, as well as from mathematics, and second, the strengths that each group brings to the class make the experience interdisciplinary for all.

Naomi D. Fisher

The **Mathematicians and Education Reform (MER) Forum** seeks the effective participation of mathematicians in mathematics education reform at the K-12, undergraduate, and graduate levels, and the recognition of the importance of these efforts to the well being of the mathematics community. The MER Forum envisages the pursuit of educational reform through informed discussion of educational issues, thoughtful responses to changing educational conditions, and the promotion of exemplary programs. The creation and support of a network of mathematicians with a sustained commitment to mathematics education is central to this vision.

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Notes on Teaching Undergraduate Mathematics

Upper-level Math Courses for Math Outsiders

by Stephanie Frank Singer

"I failed math twice, never fully grasping probability theory. I mean, first off, who cares if you pick a black ball or a white ball out of the bag? And second, if you're bent over about the color, don't leave it to chance. Look in the damn bag and pick the color you want." — fictional bounty hunter Stephanie Plum, in *Hard Eight* by Janet Evanovich.

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As any math-lover knows, mathematics permeates the world, including many other academic disciplines. Yet, as any teacher of college mathematics knows, it is not easy to present applications of mathematics successfully in the classroom. I have had some success presenting applications of analysis and algebra to physics students. Learning the material and preparing it for presentation was a long, slow (yet at times frantic) process, but the rewards just keep on coming. Perhaps recounting my experience in these pages will encourage some readers to embark on an analogous project with reasonable expectations.

My own journey was more a ramble than a well-planned tour. I did not have *a priori* plans to develop courses – I just wanted to get out of the house (of pure mathematics for its own pure sake) and get some perspective. I knew of and admired many applications of numerical analysis and other computational techniques, but I don't have the right combination of talents for that kind of work. Was there a solid basis to the widespread praise for "mathematical maturity" and "mathematical thinking?" Forget the Emperor and his new clothes – what about the Queen of the Sciences?

Success in academic endeavors is not easy to measure, but there is some evidence that my foray into physics made a significant impact. The three upper-level mathematics courses I taught on applications to physics (at Haverford College) attracted an unusually large audience, with enrollments ranging from 8-12 students in a department where 3-6 is the norm. Several of these were physics and chemistry students who would not normally take an upper-level mathematics elective. Student reviews of the course were almost uniformly positive, and it was not unusual to get comments such as "now I know what analysis and algebra are good for." Two of the courses attracted three professors as auditors. Two physics majors from my courses are now graduate students in mathematics; several more are mathematically savvy graduate students in physics. My first book on physical mathematics is selling well. The NSF is funding my efforts to write a second one.

Specifically, the three courses were "Lie Theory and Physics" (predicting mass and spin as consequences of the Lorentz symmetries of Minkowski space), "Differential Geometry with Applications in Physics," and "Lie Groups and Physics" (predicting the structure of the periodic table as a consequence of the spherical symmetry of the Coulomb force). The target audiences were math, physics and physical chemistry majors at the junior and senior undergraduate level. The prerequisites were solid understanding of linear algebra and vector calculus, as well as scientific or mathematical "maturity", as indicated by two junior-level courses in either math or physics (one of which might be taken concurrently). As a minimum, my students had taken a semester or two of analysis or algebra, or an advanced mechanics course (classical or quantum). My first book, *Symmetry in Mechanics: A Gentle, Modern Introduction,* was published by Birkhauser Boston in 2001. My second book is being written with support of a Course and Curriculum grant from the National Science Foundation and will be published by Springer Verlag.

The first, crucial part of the project was my own immersion in the language and culture of physics. To motivate physics students to study mathematics, I had to convince them that the mathematics would be useful to them, on their terms. So I had to understand their point of view. I audited undergraduate courses in classical and quantum mechanics. I listened to students and professors of physics. I went to physics colloquia and invited physicists to speak in the math department. I learned to use their names for concepts and procedures. For example, I learned that they often use derivatives, but rarely use the word "derivative"; instead, they expand a function in a (Taylor) series and calculate, eventually dropping all but the linear terms. This is equivalent to differentiating (and using various theorems of differentiation, such as the product rule) but looks entirely different. There is an excellent reason for a physicist to differentiate via series expansions: she can do it to any kind of object, not just to functions. No need to introduce the axiomatics of Lie algebras – just write elements of your group as a series near the identity! No need to define higher derivatives! Just calculate and see if the answer looks interesting.

If you want to bring another discipline into your

continued on page 10

Project Update

Excellence in Undergraduate Mathematics

The joint AMS-MER three-year project on Excellence in Undergraduate Mathematics: Confronting Diverse Student Interests, funded by NSF, is aimed at helping mathematics and mathematical science departments strengthen their undergraduate programs, especially targeting the courses below calculus and the upper level undergraduate curriculum. The center of the project is a series of six national workshops, two each academic year.

Having completed three of the planned six national workshops, we can take a mid-course look at what is happening and what we are learning. The first workshop in December, 2001 at Arizona State University on *Excellence in Undergraduate Mathematics: Mathematics for the "Rest of Us"* looked at the mathematical needs of students who complete their math requirements without taking calculus, whereas the second and third workshops— *Excellence in Undergraduate Mathematics: Mathematics for the Non-traditional Major* in May, 2002 at Washington University, and *Excellence in Undergraduate Mathematics: Diversification of Upper-level Mathematics Programs* in November, 2002— looked at how departments can support advanced undergraduate students who are planning careers in business, industry, or government rather than studying graduate mathematics.

First, some statistics about the departments that have participated in the workshops. 63 departments have participated in at least one workshop: 10 departments have participated in two of the three workshops, and 4 departments have participated in all three workshops. The departments' institutions, which represent 33 states and the District of Columbia, run the gamut of types of institutions of higher learning: 8 are 2-year colleges, 12 are 4-year colleges, 26 are comprehensive universities, and 16 are research universities. Further, these institutions as a group reflect the diversity of students across the nation: 4 institutions have student populations that are 69%-100% women; 7 institutions have student populations of more than 30% African American students, including 2 Historically Black Institutions; 4 institutions have student population that are 6%-28% Native American; 1 institution has a student population that is 65% Hispanic; and 1 institution is a university for deaf students.

Remarkably, there is a consensus among these departments about the issues they face at the lower level curriculum below calculus and the issues they face with regard to the upper level curriculum. The first thing to note is the asymmetry between student enrollments in the lower level courses and the upper level courses. Based on our surveys of the departments about their enrollment figures, typically 40%-50% of a department's enrollment is in courses below calculus (this percentage is closer to 100% for some of the 2-year colleges), but typically only 1.4%-2.6% of a department's enrollments are in courses above the calculus sequence and linear algebra. Depending on your favorite metaphor, there's a leak in the pipeline or the filter is clogged.

Getting ahead for a moment to the question of *what to do?* there are strong parallels in how to address change in the situation of the lower level curriculum and the upper level curriculum. In both situations, creative thinking is needed about the curriculum to develop courses that distinguish the ways in which mathematics is useful and important to students. At the lower level, specialized courses aimed at liberal arts students, students majoring in sciences that do not require calculus, and elementary education majors, for example, would be appropriate. At the upper level, the curriculum can be opened to offer courses that span the interests of computer science or physics majors, as well as math majors; to develop internships to allow students to work on industrial or business related math problems; and to include courses in financial mathematics or scientific computation, for example, that could be considered professional preparation for careers in mathematical fields.

These approaches require that departments are more aware of the multiplicity of interests of their students and potential students, and to think "outside the box" of the department itself and build ties with faculty in other disciplines and contacts with professionals outside the college or university.

Lower level mathematics curriculum

Some faculty will explain the high drop rates and failure rates as the result of the poor math skills of the students and their lack of motivation. But the courses themselves need to be scrutinized. If you imagine a 2x2 matrix for a course with the columns designated "course is okay" and "course is not okay" and the rows designated "students are okay" and students are not okay" you are led to consider four possibilities: (1) both the course and the students are okay, (2) the course is okay but the students are not prepared, etc., (3) the course lacks coherence etc., although the students do okay, and (4) the course is ill-conceived and the students do not do well. Departments concerned about the second situation see a need for better placement tests and advising. The fourth case suggests that there may well be a connection between the content and instruction in the course and the poor performance of the students.

College Algebra, for example, lumps together students with many different majors. As Benny Evans, Oklahoma State University, summed up, "The students don't like to take the course, and the faculty don't like to teach it."

Instruction in these courses is mostly by non-tenure track instructors, either adjunct instructors or graduate students. In some cases, this situation may be a boon to the students, since the instructors excel in teaching, having taught at the high school or community college level. In the case of graduate students, they are usually learning on the job for good or nil. But in neither of these cases, is the tenure-track or tenured faculty of the department establishing connections with these students.

Three examples of courses that were presented at the ASU workshop for targeting particular students and designing mathematics courses that make meaningful mathematics accessible to these students are *Functions and Change*, *Mathematics in Education*, and *Mathematics for Effective Thinking*. *Functions and Change* was developed at Oklahoma State University in response to having surveyed faculty in such fields as ecology, botany, and social sciences about their expectations in requiring their majors to take College Algebra. The new course presents functions in four different ways— by formulas, tables, graphs, and in verbal form— and students learn to move from one representation to another. The exponential and logarithmic functions are prominent and exponential regression is used when modeling nearly exponential data. The use of graphing calculators is essential to how the course is taught. *Mathematics in Education* at CUNY Brooklyn College, targeted at elementary education majors, focuses on the development and communication of mathematical reasoning in the context of developing and extending the K-6 mathematics curriculum. The instruction uses eclectic approaches, including varied forms of assessment and manipulatives used in elementary school, that build on future teachers' fundamental motivation to help their own students learn. *Mathematics for Effective Thinking*, which is based on *The Heart of Mathematics: An invitation to effective thinking* by Edward Burger and Michael Starbird, is aimed at presenting "great moments in mathematics" for liberal arts students taking their last mathematics requirement. The goal is to teach exciting mathematical ideas and to focus on the method of analysis that generated these ideas to help students build sharper skills for analyzing life issues that transcend mathematics.

Upper level curriculum

At the upper level curriculum the overwhelming issue is that too few students are interested in the traditional curriculum designed for students intending to go to graduate school— or at least how that option is presented to them. This is not to say that there is not a pool of capable students who are interested in advanced undergraduate mathematics, but there needs to be a hook to bring them into advanced courses. In fact, there are several approaches to recruiting students, including recruiting students to study the traditional curriculum.

Integration of mathematical material that bridges mathematical fields and integrates traditional curriculum and new topics for undergraduates may create interest in studying mathematics and recruit strong mathematics students who are not math majors. Examples of such courses are *Groups and Representations* at Oklahoma State University and *Cryptological Mathematics* at the University of North Dakota. *Groups and Representations* is an introduction to groups, group actions, symmetry groups, and representations of groups and characters, and is appropriate for engineering and science majors as well as math majors. *Cryptological Mathematics* puts equal emphasis on cryptanalysis and cryptology and aids students in making connections between various subdisciplines of mathematics. While the course is suitable as a capstone experience for math majors, it is also suitable for computer science majors.

Scientific Computing at Arizona State University is an example of a course to prepare students with a bachelor's degree in mathematics to be competitive in the workforce. The course, which is designed for majors in mathematics, physics, chemistry and computer science, surveys and applies programming languages, libraries, and scientific visualization tools.

An intriguing idea is to think about the traditional math major as though it were a new program, and ask the question, "What professional skill should the major develop?" In essence this is what the mathematics department at Spelman College did. As a result, the department has a strong focus on getting their students involved in research experiences in mathematics. The department has been very successful in getting students to go on to graduate studies and to earn doctorates in mathematics and other fields. ■

MER Forum Announcements ..

MER Program at Annual Joint Mathematics Meetings

January 15 - 18, 2003 **Baltimore, Maryland**

The schedule of presentations for the special session is on pages 8 and 9. Abstracts for the presentations can be viewed on the MER homepage and the AMS website. Please consult the official program for all locations for the Special Session and the MER Banquet. The time and location of the Friday session on the AMS-MER project on *Excellence in Undergraduate Education: Confronting Diverse Student Interests* will be announced in the MER eNews and posted on the MER webpage. Tickets for the MER Banquet may be purchased when registering for the meeting.

Wednesday, January 15		
	Special Session on *Mathematics and Education Reform*	
	Session I	**8:30 - 10:55 AM**
	Session II	**2:15 - 5:45 PM**
Thurday, January 16		
	Special Session on *Mathematics and Education Reform*	
	Session III	**8:30 - 11:50 AM**
	Session IV	**1:00 - 3:30 PM**
	MER Banquet	**6:30 - 9:30 PM**
Friday, January 17	**Time and place TBA** **Gathering for departments participating in the AMS-MER NSF project on *Excellence in Undergraduate Mathematics: Confronting Diverse Student Interests***	

Notes on the Special Session

The 2003 Special Session on Mathematics and Education Reform spans K-12 education and undergraduate education. The Wednesday sessions focus on precollege issues. In the morning, a theme introduced last year— Interpretations of Deep Understanding of High School Mathematics and Professional Education of High School Teachers— is revisited and broadened to consider similar questions with respect to K-8 mathematics teachers. The current theme *Mathematics for Teachers and Mathematics for Teaching: Examples from Elementary and High School Preservice and Inservice Programs* is a continuing exploration of what may be general principles for designing courses for prospective and practicing K-8 and high school teachers, respectively. The unifying perspective among the speakers is a concern that education of preservice and practicing teachers (1) work within a context that has strong connections to the classroom either because it has links to the school curriculum or offers material that the teachers can bring into their classrooms, and (2) puts an intellectual spin on the teachers' understanding of the school curriculum and opens up possibilities for gradually transforming the school curriculum. The notion that teachers need a specialized understanding of and knowledge base in mathematics that is related to, but more sophisticated than, the school curricula underlies these approaches to mathematical education of teachers.

The Wednesday afternoon program, co-organized by Eric Robinson, Ithaca College, on *Bridging the Gap: A common ground for high school mathematics and college mathematics* has its antecedents in a 2001 program on standards-based high school curricula. The session identifies commonalties, as well as differences, to consider the possibilities of a

... news briefs ... updates ...

smooth progression from high school mathematics to undergraduate mathematics. This is a two pronged investigation of new high school curricula and related expectations of the capabilities and expectations of the students who have learned mathematics through these new curricula. Although we usually think of the high school curriculum as designed for preparation for the undergraduate curriculum, faced with "brave, new" undergraduates, faculty may need to rethink college curricula and instruction.

Thursday's program is in the realm of undergraduate mathematics. The Thursday morning program, which is organized in cooperation with CRAFTY, reports on and discusses the implications for undergraduate education of the new CUPM (Committee on the Undergraduate Program in Mathematics) Curriculum Guide, to be published in 2003, and the CRAFTY Curriculum Foundation Workshops. Together, these reports consider undergraduate mathematics curricula for majors and non-majors, and for students interested in a whole host of fields that use mathematics.

Thursday afternoon's program, the concluding session of the special session, is devoted to a panel on *Strategies for Increasing the Diversity of Students in Mathematics*. The panel is conceived to complement the MAA Contributed Papers Session with the same title on Friday at 8:00-10:55 am. The MAA session will feature six programs exemplifying successful strategies. For Thursday's panel, the six panelists are asked to consider critical points in planning, implementing, and sustaining a successful program. The issues to be discussed are student recruiting, faculty development and recruitment, critical stages in retaining students, institutional or governmental policies that help or hinder the process, essential resources (time, money, and space), essential attributes of the program structure, "best advice" based on personal experience, things to avoid, and assessing the strengths and weaknesses of the program.

Invitation to Departments Meeting on Excellence in Undergraduate Math

The MER Friday program on the current NSF funded AMS-MER project *on Excellence in Undergraduate Mathematics: Confronting Diverse Student Interests* is being organized for departments that have participated in one or more of the project workshops to discuss the progress they are making, and obstacles they are encountering, as they implement plans for new or revised courses. We extend a welcome to all members of MER and their colleagues to attend the session, whether or not they have already attended a project workshop. This is an opportunity to hear firsthand what departments are doing to strengthen their undergraduate programs. The concerns driving these efforts are getting more students to study more mathematics. The workshop experience engages departments in assessing their needs and resources, considering how to adopt or adapt successful efforts from other departments, or developing their own programs. FYI, three more workshops will be offered through the next academic year.

2003 MER Membership

Renewal notices for MER membership will be coming to you soon. Dues for the 2003 one-year individual membership, beginning January, 2003, are $25. Individual dues for students are $15. Membership in MER includes subscription to the bi-annual MER Newsletter and Special Issues, and access to the MER eNews, an electronic auxiliary. We at MER look forward to your continued participation in the MER Forum.

New members are welcome! To obtain an MER membership application form, send your mailing address to mer@math.uic.edu, or download a copy of the form from the MER homepage at http://www.math.uic.edu/MER/pages/join.html.

AMS-MAA-MER SPECIAL SESSION on

Mathematics and Education Reform

SCHEDULE

Wednesday, January 15, AM

Mathematics for Teachers and Mathematics for Teaching: Examples from Elementary and High School Preservice and Inservice Programs

8:30 - 8:50
Seeing the Connections: Promoting Profound Understanding of Secondary Mathematics
Steve Benson, Education Development Center
Al Cuoco, Education Development Center

9:00 - 9:20
The Role of Mathematical Content in Professional Development
Carolyn R. Mahoney, Elizabeth City State University
Dick Stanley, University of California, Berkeley

9:30 - 9:50
Learning Mathematics on a New Playing Field—Discrete Mathematics
Valerie A. DeBellis, East Carolina University
Joseph G. Rosenstein, Rutgers University

10:00 - 10:20
Integrating Mathematics and Science with Preservice K-8 Teachers
Philip Wagreich, University of Illinois at Chicago

10:30 - 10:55
Discussion

Wednesday, January 15 PM

Bridging the Gap: A common ground for high school mathematics and college mathematics

2:15 - 2:40
Opportunities and Challenges in the School-Undergraduate Continuum, Part I
Eric Robinson, Ithaca College

2:45 - 3:10
Opportunities and Challenges in the School-Undergraduate Continuum, Part II
Bill Haver, Virginia Commonwealth University

3:15 - 3:35
Some Articulation Issues between High School and College Mathematics Education
John Maceli, Ithaca College

3:45 - 4:10
What Graduates of Reform Mathematics Programs Bring to College Mathematics
Dan Fendel, San Francisco State University

4:15 - 4:40
Mathematical Content in Standards-Based Curricula
Sol Garfunkel, COMAP

4:45 - 5:45
Panel on the Mathematical Needs of Teachers
Moderator:
Eric Robinson, Ithaca College
Panelists:
Joan Ferrini-Mundy, Michigan State University
Ira Papick, University of Missouri
Amy Cohen-Corwin, Rutgers University

AMS-MAA-MER SPECIAL SESSION on

Mathematics and Education Reform

SCHEDULE

Thursday, January 16 AM

Themes from the CUPM Curriculum Guide
Co-Sponsored by CRAFTY

8:30 - 8:50
Introduction and Background for "Undergraduate Programs and Courses in the Mathematical Sciences: A CUPM Curriculum Guide"
Harriet S. Pollatsek, Mt. Holyoke College

9:00 - 10:20
Panel on Undergraduate Programs and Courses in the Mathematical Sciences: A CUPM Curriculum Guide
Organizers and Panelists:
Harriet S, Pollatsek, Mt. Hoyoke College
Susanna Epp, DePaul University
Susan Ganter, Clemson University
Bill Haver, Virginia Commonwealth University

10:30 - 10:50
Mathematical Thinking and the CUPM Curriculum Guide
Susanna S. Epp, DePaul University

11:00 - 11:20
Undergraduate Issues for Research Universities
David Bressoud, Macalester College

11:30 - 11:50
The CUPM Curriculum Foundations Project: Looking at the First Two Years
Susan Ganter, Clemson University

Thursday, January 16 PM

Strategies for Increasing the Diversity of Students in Mathematics
In Coordination with the MAA Contributed Papers Session of the same title

1:00 - 2:30
Forum on Strategies for Increasing the Diversity of Students in Mathematics
Moderator:
Naomi Fisher, University of Illinois at Chicago
Panelists:
Dennis Davenport, Miami University
Raymond Johnson, University of Maryland, College Park
Roosevelt Johnson, National Science Foundation
Robert Megginson, Mathematical Sciences Research Institute
Teri Murphy, University of Oklahoma
Ami Radunskaya, Pomona College

2:40 - 3:30
Questions and answers, and discussion

Upper-level Math Courses for Math Outsiders
continued from page 3

mathematics classroom, I recommend that you choose a field of innate interest to you. Don't worry about particular applications as you immerse yourself in that discipline, and resist the temptation to ask people in the other discipline to talk in your language. Cultivate relationships with practitioners of the discipline. Go to their colloquia and find a way to invite them to your department to speak.

By listening I learned what motivates physicists – they are interested in making predictions about physical phenomena so that they can check their explanations with experiments. For instance, their cavalier expansions of anything and everything into series may not always be mathematically well-grounded, but they do generate predictions. Once I understood what physicists wanted, I was no longer confused by their apathy toward definitions and proofs. Yet as a pure mathematician, I was disappointed. Could it be that proofs and definitions are of no use whatsoever to physicists, or important only as mental calisthenics, about as relevant as, say, string quartets?

After living among the physicists for a while, I found a specific question to ask: can one use mathematics to predict physical phenomena? By posing this question to colleagues (physicists and mathematicians interested in physics) I eventually found a very satisfying set of answers involving applications of representation theory to quantum mechanics. Because the symmetries of any physical system form a group, and because the generally accepted model for quantum mechanical systems is a vector space, a quantum mechanical system with symmetry has an associated representation – a group homomorphism from the symmetry group to the group of linear operators on the vector space. Thus theorems about representations can be used to make predictions about quantum mechanical systems with symmetry.

Although mathematics is surely relevant to almost every discipline, you should be prepared for the possibility that the mathematical method simply does not apply usefully to the discipline you have chosen. The goal is not just to see mathematics in the other discipline for oneself, but to convince others that mathematics is important to their endeavors. A little bit of zen in the attitude is useful here: to find enlightenment, one must first let go of one's desire for enlightenment. Only when you can put aside your own innate enthusiasm for mathematics can you view it with an eye dispassionate enough to fairly judge its applicability.

Once I found my topic, my work became more focused. I had a lot of material to learn. Some I learned from books (especially Sternberg's *Group Theory and Physics*, a goldmine of applications), some from colleagues, some from students. But at that point I saw the big picture clearly, so I outlined and advertised an upper-level mathematics elective course. Soon my work became intensely focused – on learning the material I was to present in the next lecture. The devil is indeed in the details, but when the goal is clear the devil is easier to vanquish.

Teaching the courses was a pleasure. Because the audience was so varied, because the math majors' strengths and weakness complemented the weaknesses and strengths of the physics majors, meaningful class discussions arose naturally. Students' presentations were easily motivated and generally successful. We were a team with a common goal: understanding the material and its importance, and I felt more like the team captain than like the coach.

Once you get to the stage of structuring the course, take advantage of the diversity of students' experiences. Recruit students from both mathematics and the other discipline and don't worry too much about their disparate preparations. Rather, find ways to encourage them to teach each other. The more dialogue you generate, the less work for you and the more the students will gain. It's a win-win situation.

I reaped unforeseen rewards as well. I gained a deeper understanding of representation theory, as well as a deeper understanding of physics. I had the pleasure of teaching topnotch students from other departments. In a broader sense, I found an extremely satisfying outlet for my own combination of talents, and a receptive and grateful audience for my speaking and writing.

In summary, I heartily recommend exploring another discipline with an eye toward presenting it in mathematics courses. Here is my advice in a nutshell:

- Choose a field that interests you.
- Immerse yourself in the foreign discipline, as you would in a foreign language and culture.
- Find colleagues in the other discipline interested in talking about mathematical issues.
- Be prepared for the possibility that mathematics is **not** of use in the other discipline.
- In class, encourage exchanges between math majors and majors in the other discipline.

Good luck!

About the author: Stephanie Frank Singer recently resigned her tenure at Haverford College. She is writing her second book, "The Hydrogen Atom: An Introduction to Group and Representation Theory." She can be contacted through her website, www.symmetrysinger.com. ■

Undergraduate Mathematics Majors: We need more of them, *continued from page 1*

university, a department. Rarely do we hear about those funds being directed specifically towards a mathematics department. There are loads of engineers and chemists who graduate each year from our universities. Compare this to the relatively small number of mathematics majors. When we see more students majoring in mathematics and choosing the business and engineering world instead, we will see more of these individuals wishing to contribute back to the department. It really is in our best interest to have more mathematics majors.

Who ultimately has the responsibility to increase the number of mathematics majors? And once a student has decided to major in mathematics, what can be done to keep this student in the major? I believe that the current situation is rather a hit-and-miss affair. A few students are attracted to the subject and for a variety of reasons stick with the major. This is much too important a topic just to be left to chance. I would like to suggest that we have a very natural mechanism for attracting students to the deeper study of mathematics. It is our calculus classes. Every science and engineering major has to go through our calculus classes, and it is here that I suggest that we consider adding a component to attract students to our major.

When I teach a mathematics class, I am always on the lookout for interesting applications of mathematics and new career opportunities to pass on to the student. *Science,* the weekly publication of the American Association for the Advancement of Science is a great source of articles about careers and applications of mathematics. Geared to the general layman, the articles are comprehensible to the students in the calculus class. When I find an article, or a job announcement, I give copies to the student, and make a few remarks about the article. I look for short articles, rather than in-depth articles, that present the ideas in a comprehensible fashion, and for human interest articles about recent achievements of mathematical scientists. Some recent examples of articles I have handed out to students are: *Death by the Numbers, The Art of the Orbit, Bioinformatics in the Information Age, The Quandary of Quantum Information.*

It would be very useful if a periodical dedicated to helping teachers of calculus recruit students to the study of mathematics were published under the auspices of one or more organizations. This periodical might contain interesting applications of calculus, career opportunities, problems that mathematical scientists are addressing, information about graduate programs, summer internship information, ideas for REU (Research Experiences for Undergraduates) projects, new scientific endeavors that intimately use mathematics, like bioinformatics.

Recruiting students to the study of mathematics is one thing, keeping them is another. We need mechanisms to help students stay in the major, and to help faculty in these efforts.

At the departmental level I believe that there should be an office, with a staff, specifically dedicated to the undergraduate mathematics major. This office would be responsible for keeping track of the majors, *including keeping track of these students after they graduate and leave the university*. Former students can be an important source of employment opportunities for future students. Besides bookkeeping chores, this office would also have the responsibility of organizing the professional development activities that are so vital to students' careers. Resumé writing and interviewing skills workshops, the posting of summer internships, regular lectures aimed at undergraduates, graduate school opportunities, opportunities for employment in the department and the university. This office would have the responsibility of turning the undergraduate mathematics major into a marketable and professional degree.

The national organizations, AMS and MAA, could do more to increase the attractiveness of the undergraduate mathematics major. There are very few activities for undergraduates at regional and national meetings. In particular, very few recruiters from industry show up at our national meetings. Certainly, there are large numbers of students who receive a master's degree in mathematics and will not pursue a Ph.D. Besides the bachelor's degree recipients, these master's degree students are also looking for employment. Recruiters should be at our national meetings.

In closing, I would like to return to the theme at the very beginning of this article . What is my function as a teacher of mathematics, in particular, as a teacher of calculus? If that function is simply to present the material in some impersonal manner, then I fear for our profession and for our departments. Calculus is our bread and butter. Calculus provides employment for our graduate students and it should give us the opportunity to showcase the beauty and utility of mathematics. Recently I saw an advertisement for calculus lectures on video. I believe that the time will come when a video calculus course would present the material in a manner more interesting and relevant than any of us could possibly do, since technology could be incorporated in clever ways to exemplify the ideas. If that comes to pass, why should a university hire us to give boring and impersonal lectures? What a video cannot presently do is to look into a student's eyes and say:

"You are an amazing student! I am very impressed by your question, by your solution, by your remarks. Have you thought of becoming a mathematics major? I recently heard of a summer internship opportunity that would be perfect for you. Stop by my office today so that I can tell you about it." ■

Workshop news

Preliminary Announcement

AMS-MER Workshop on

*Excellence in Undergraduate Mathematics: Mathematics for Teachers and Mathematics for Teaching**

Ithaca College, Ithaca, NY
Thursday-Sunday, March 13-16, 2003

The mathematical preparation of K-12 teachers is an issue of great concern. Good citizenship obligates mathematics departments to take seriously their responsibility to educate future teachers; and self interest should spur mathematics departments to do their job well so as to benefit directly from good teaching at the K-12 level. Ideally, mathematics courses for future teachers serve three purposes: present content that teachers should know, exemplify good instruction, and relate to the K-12 world of teachers.

The workshop will focus on how mathematics departments are addressing the issues of:

- Mathematics for Teachers— the mathematical content knowledge and mathematical skills teachers should have
- Mathematics for Teaching— undergraduate mathematics experiences relating to the K-12 teaching profession.

Funding for the workshop is provided by the National Science Foundation.

* This is the fourth workshop in the six-workshop series on
Excellence in Undergraduate Mathematics: Confronting Diverse Student Interests

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