MER Newsletter

Mathematicians and Education Reform ...Forum...

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notes on undergraduate teaching

Undergraduate mathematics majors: We need more of them

by William Yslas Vélez, University of Arizona

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

I firmly believe that students should major in mathematics. In particular, students who arrive at the university without a major should be encouraged to choose mathematics for their major. Much of my latter professional life has been dedicated towards implementing this belief. In fact, I often tell students in the mathematics classes that I teach that my function as their teacher is not to teach them the subject matter. (They have a good book for that; they should read it.) My goal as their teacher is to convince each and every one of them to change his/her major and to become a mathematics major. I tell them that the material I will be presenting to them is simply so interesting and so useful that it, not me, will convince them to change their majors to mathematics. Mathematics is the most fundamental, the most interesting, the most fascinating of subjects. How can I fail to convince the students of this most obvious of facts? In fact, I fail most of the time, but I do try.

It would be wondrous if all university departments had a mandate to present their subject matter as if it were the most interesting subject in the world. Wouldn't it be wonderful if students complained that all of their classes were so interesting that they were having a difficult time deciding what to major in?

The goal of this paper is to convince mathematicians and mathematics departments that we should increase the number of mathematics majors at our universities. Before I address this question I would like the reader to think about the following questions:

1. Is mathematics just a service department to the university?
2. Who should be majoring in mathematics?
3. What can one do with a bachelor's degree in mathematics?
4. Is the undergraduate degree in mathematics a professional degree?
5. What are the students' objectives in majoring in mathematics?
6. What benefits would accrue to a department by having more mathematics majors?
7. What are the faculty's objectives in having students major in mathematics?
8. Should we, as mathematics faculty, attempt to increase the number of mathematics majors? If it is not the faculty's function to recruit students, then who should do it?
9. If it were decided to increase the number of mathematics majors, what should a faculty member do, what should the department do, what should the national mathematics organizations do to reach this goal?
10. Students who choose to major in engineering, and most of the sciences, have to take calculus. Shouldn't we re-think our calculus courses so that they serve as a recruiting tool for our majors?

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Most of us bristle at the thought that mathematics is just a service to the university. Yet when we look at the makeup of our classes, it sure looks that way. The next time that you teach a calculus class, count the number of mathematics majors. In all likelihood, the percentage of mathematics majors in that class will be a single digit. In fact, I decided to carry out this experiment for the calculus classes that I have taught in the recent past. In our department we offer a three-semester calculus sequence with all of our classes being taught in small sections. Here is the data:

1st semester Calculus, Fall 1998:
35 students, 0 math majors;

2nd semester Honors Calculus, Spring 1999:
25 students, 1 math major;

2nd semester Honors Calculus, Spring 2000:
15 students, 3 math majors;

1st semester Honors Calculus, Fall 2001:
28 students, 0 math majors.

This sure looks like a service department to me. This small experiment indicates something even more depressing for our profession. The students who are very well prepared in mathematics, say the ones enrolling in the honor's sections, are not choosing mathematics for their major when they arrive in college. We are not communicating the opportunities that exist for mathematics majors to the high school community.

mathematics major, and that I will serve as the student's advisor. This is a shocking experience for students. Most have never thought of this option. To make matters even more shocking, a student might reply that he/she has a terrible grade point average. He/she failed calculus the semester before. How on earth could he/she become a mathematics major? I point out, and this I tell the student in the strictest confidence, that I didn't fail calculus the first time that I attempted it because I had to drop it. I could not understand anything that the professor was saying. In my first semester in college I dropped calculus and enrolled in college algebra and trig. It gets even worse here. I earned a D in college algebra and trig, and another D in chemistry. So, after my first semester in college, I had nine units of D. I took first semester calculus in my second semester and completed it with a C. In my second year of college I continued the calculus series. By the end of my third semester in college I decided that I was not only going to major in mathematics, but I was going to get a Ph.D. in it.

Did I look like a promising mathematics major after my first year in college? Has the student done worse than this, I ask? I point out that I have had a very satisfying career as a mathematician, in spite of my shocking start. I was able to complete my bachelor's degree in four years and then go on for a Ph.D. The fact that I decided to study mathematics has had a marked impact on my life and the lives of my family. I have been given the tools to address a variety of technical questions, both in academia and in the world.

"The students who are very well prepared in mathematics...are not choosing mathematics for their major when they arrive in college. We are not communicating the opportunities that exist for mathematics majors [.]"

It has always been my assumption that mathematics is beneficial to students' careers. The more a student knows and understands mathematics, the more success that student will have in future technical courses. So, why aren't all students mathematics majors as undergraduates?

Can I be serious in asking this question? Let me tell you about my attitude towards this. When I teach a mathematics class, I strive to have every student in the class come in to see me for 15 minutes. During this visit I inquire as to the student's interests, and ask: *what are your goals? where are you headed? how are you doing in your classes?* and *have you thought of graduate school?* I also inquire as to his/her major. If a student does not have a major declared, then I suggest, (this is way too mild a description of what I do), that the student become a

If the student has some interest in mathematics, and is willing to work very hard, I tell the student that I would be more than happy to serve as his/her advisor. In this role I will work to develop a program of study that will engage the student and will lead to a bachelor's degree in mathematics. If the student is able to maintain a good grade point average, I will also work to find that student summer internships and employment in the department. My goal is to integrate that student into the scientific life of this country. Hopefully this integration will occur at the departmental level, the university level, and the national level.

If the student does not want to become a mathematics major, either because the student already has a major or finds the thought of becoming a mathematics major too

intimidating, I leave the student with the following thought. If, in the future, you need to talk to some concerned faculty member about your career choices, send me an email message and I will be more than happy to meet with you. This final thought is written down and handed to the student. I have a one-page worksheet that I use when I advise minority students in my calculus advising program. Though this worksheet is meant for minority students, it works equally well with all students. The worksheet is printed on page 10.

So, who should become a mathematics major? This is a central question for our profession. In answering this question, we have to understand what our goals are for the undergraduate mathematics major.

If our vision for the undergraduate degree is that the student will go to graduate school in the mathematical sciences, then perhaps we should not make any major changes in the way that we operate. If the job market for mathematicians improves, then students will hear about it, and we will see a slight increase in the numbers choosing to pursue a graduate education. Or we can increase our efforts to recruit abroad, and thereby find sufficient numbers of students to fill the needs of our graduate programs. If the job market stays the same, or declines, then there is no need to increase the pool of candidates.

I should point out that this course of action does nothing to increase the diversity of the professorate. The minority population is terribly underrepresented in the mathematical enterprise of this country. If a course correction is not made, then the makeup of the professorate will not change.

There is another view. Producing a mathematically literate population would be beneficial to our society. Mathematics provides the skills and the point of view that our citizenry needs to address the complex problems that confront us. It strikes me that if we, as professional mathematicians, believe in the efficacy of our subject then we would want to have more students major in mathematics.

It is this latter view that I espouse. I believe that choosing mathematics as a major will not only benefit the student, but it will also benefit society. I don't believe that you have to be an A student to choose mathematics as a major. I have seen students struggle through our mathematics courses, determined to complete the degree in mathematics. Some of these students have been able to use their mathematical training to obtain technical positions, which they would not have done without the training that a degree in mathematics has provided them.

For the rest of this paper I will forge ahead with the assumption that more students should major in mathematics. Now what? What would a student do with an undergraduate degree in mathematics?

I encourage students to couple their mathematical studies with a supporting subject. Of course, the traditional sciences, physics, chemistry, biology, and geosciences, do very nicely. A supporting minor in economics or finance also looks very attractive. The business world could use more mathematically trained individuals. I strongly encourage students to take as much computer science as possible. This is particularly important if students are to apply for summer internships. Knowledge of programming languages is an absolute necessity in order to be considered for a summer internship. It would also be helpful if students knew a computing platform in which they felt comfortable.

Mathematics departments have to be much more aggressive in finding employment opportunities for their undergraduates. These employment opportunities are internal and external. It is a fact of life that students need money to continue their education. Employment opportunities inside a department can be an effective strategy to recruiting students into the major. Engineering and the sciences have always employed students to work in their labs. Mathematics departments need to also create these opportunities.

In my own department we have had student computer laboratory assistants for many years. Not only do these students provide a necessary service to the department, but they also learn valuable skills. Of course, having funds to support Research Experiences for Undergraduates (REUs) is a plus. Recently my department created new positions, the Undergraduate Teaching Assistants (UTA). The website, http://www.math.arizona.edu/~mcenter/research/research.html, contains information about UTAs. The UTAs are hired to work with a faculty member in the teaching of a course. The UTA will run tutoring sessions for the class, perhaps grade papers, help run outside course assignments, and sometimes participate in the class. In advising students I suggest that by the time they graduate with an undergraduate degree in mathematics, they should have participated in an REU, and have held a UTA and a summer internship. This collection of experiences, together with a solid background in mathematics, will make our undergraduates attractive to both graduate schools and industry.

Summer internships in industry for our mathematics

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majors are not part of the mathematical culture. (If you have not had much experience in obtaining summer internships for students, you might look at the following website that contains links to internship opportunities, http://m707.math.arizona.edu/~restrepo/AMII/amii.html.) I believe that departments have to implement a program of outreach to industry. Too often I have seen recruiters arrive on campus seeking engineers, and ignoring mathematics majors. We know perfectly well that a mathematics major with a science background and knowledge of computing could function as an engineer. In fact, I had the following conversation with a group of engineers. I had visited a business in an effort to find summer internships for our mathematics majors. The engineers there pointed out that a common trait in the new engineers that they hired was that they would compute first and think later. They mused that it would be nice if the new engineers could do some analysis first before launching into the time intensive simulations. If the engineers had more mathematical training, they might be more prone to do this. I, of course, pointed out that many of our mathematics majors did in fact have the computing skills that were necessary and that they should think about hiring some of them to fill their need for engineers.

"It is a curious fact that if a person graduates with a degree in engineering, computer science, or chemistry, then that person is considered to be an engineer, a computer scientist, or a chemist. This is not so in mathematics."

It is a curious fact that if a person graduates with a degree in engineering, computer science, or chemistry, then that person is considered to be an engineer, a computer scientist, or a chemist. This is not so in mathematics. We don't call students with bachelor's degrees in mathematics mathematicians. You have to have a Ph.D. for that. I believe that we need to change this situation. We need to increase the professional activities for our undergraduates. Have you noticed the variety of professional activities aimed at undergraduate engineering majors that take place in the Colleges of Engineering? In engineering, students begin preparing for their profession as early as their freshman year. Resumes have to be prepared and interviewing skills have to be addressed. The hunt for summer internships is a must. Engineering firms are courted and invited to send representatives to speak to students. The mathematics departments should emulate this activity. I would like to suggest the following activities:

- Every mathematics major has a resume, and this resume is updated every semester.
- Mathematics majors should be introduced early to the services that the university provides for career development.
- If a math club exists on campus, then this club should enact professional development activities. In particular, the club should include activities encouraging its members to apply for summer internships.
- Someone in the department should be assigned the responsibility for finding summer internships for its students.
- Faculty should meet with recruiters to encourage them to hire mathematics majors.
- Faculty should seek out summer positions for themselves in industry and government labs.
- At least once per year a meeting for undergraduates should be held announcing the opportunities for summer internships that are available.
- Annual announcements that list the students that have held summer internships should be produced and made available to the undergraduate mathematics majors.

To be continued in the Fall, 2002 issue.
Preview of part 2:

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? ... [T]he 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. ...[W]e 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.... [We should] consider adding a component to our calculus classes to attract students to our major. ■

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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

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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." ■