The Mathematics Major in 2010: What Should Graduates Know?

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Beginning a meaningful dialogue:

It is imperative that college teachers of mathematics periodically examine the curriculum and the methods being employed in the teaching of mathematics so that they might determine how well these serve the needs of students and other stakeholders. Surveying the literature and determining changes in the workplace should be a part of any such periodic examination. However, a recent report from the Mathematical Association of America [1] indicated that the curriculum for the undergraduate major in mathematics has undergone very little change over the past thirty years. This seems implausible given the changes in the many different fields in which mathematics plays a significant role, particularly computer science. Additionally, technology allows us to solve certain mathematical problems quickly and the ready availability of technology raises many questions regarding its proper use in the classroom. The MAA and each of its sections have an important role to play in these discussions on the changing face of mathematics teaching at the collegiate level. In the Louisiana-Mississippi section, the authors, along with Andrew Sterrett, formed a panel to discuss the important issues that we see related to the mathematics major in the year 2010. In this paper, we present some of the ideas which came out of this discussion and hope that they serve as a beginning for a meaningful dialogue.

It appears we're doing a good job:

The book *Jobs Rated Almanac* by Les Krantz [4] ranks 250 jobs from the best to the worst in a number of categories. It is interesting to note the top six jobs in overall satisfaction in this listing: (1) website manager, (2) actuary, (3) computer systems analyst, (4) software engineer, (5) mathematician, and (6) computer programmer. All six of these are potential jobs for a mathematics major, particularly if the graduate has at least a minor in computer science. This listing raises several questions. Why do people who can excel in mathematics end up with jobs that are considered to be the most satisfying? Are they satisfied with their jobs because they are talented problem solvers and hence are well prepared for their job? Do they have good working situations because their co-workers give them the respect every person seeks on the job? Or is it a combination of these and other factors that lead to a high level of job satisfaction?

Possibly, there is something in the traditional sequence of courses that permits students to succeed in a variety of fields. It could be argued that the current curriculum teaches students to be problem solvers and provides them with the ability to apply problem solving skills in a wide variety of settings. Another possibility might be that mathematics majors are often given immediate respect. The general public seems to purport a fear of mathematics and a general sense of awe toward people who earn a degree in mathematics. This general outlook often gives the mathematics major immediate respect in the workplace. However, it is this same fear of mathematics that may make the mathematics fraternity smaller than college mathematics faculty would like to see.

Why the need for change?

There are many forces driving curricular changes in the area of teaching undergraduate mathematics. Some of these include economic imperatives, new applications of mathematics, and the effects of technology. Consideration of the implications of some of these forces make it apparent that mathematics departments cannot be complacent. The MAA has formed the Committee on the Undergraduate Program in Mathematics and charged it to review the undergraduate curriculum in mathematics and make recommendations. Those recommendations are scheduled to emerge in 2001. For more information on this project, see Robin Wilson's recent article in the *Chronicle of Higher Education* [6], or visit http://www.maa.org/news/cupm.html.

Additionally, students and their families are demanding to be shown the value of an undergraduate degree in mathematics. In the current economic climate, students with undergraduate degrees in mathematics are finding jobs. However, for the most part, mathematics departments have not been successful in communicating the fact that graduates in mathematics are equipped for multiple career opportunities. Frequently, students who are not interested in teaching are not aware of the many other opportunities for a graduate with an undergraduate mathematics major. Consequently, in the competition for majors with departments for which marketability is better known, the poor articulation of the available opportunities for mathematics majors has kept many students from considering such a major. Hence, it is critical that, throughout the curriculum, mathematics faculty share with students the marketability of the skills they are acquiring.

Some of the issues:

Ironically, at the very time when the need for mathematically trained graduates is growing, the actual number of students who are completing degrees with a major in mathematics has been declining. According to the *Digest for Education Statistics, 1998*, published by the National Center for Education Statistics and available at http://nces.ed.gov/pubs99/digest98, the number of undergraduates who graduate with a major in mathematics has steadily declined from a high of 17,147 in 1985-86 to a low of 13,143 in 1995-96. During this eleven year period, the number of graduates in mathematics fell below the numbers for fields such as home economics and protective services. This presents another challenge to professors of mathematics at the post-secondary level. How do mathematics departments structure the curriculum and programs to make them attractive to prospective majors? Is the way in which initial courses are taught, particularly those in the calculus sequence, driving students away from mathematics as a major? Are there changes that can be made to reverse this trend? Unless college mathematics faculty successfully answer these questions, the mathematics major in 2010 may be largely irrelevant. Mathematics departments may have great programs with very few students to benefit from them. A related issue which must be addressed is the need for more teachers of mathematics. During the next decade, increasing numbers of mathematics majors at the undergraduate and graduate

levels will be seeking employment in industry and commerce. Consequently, unless current trends are reversed, there will soon be shortages not only of mathematics teachers at the K-12 level, but in colleges and universities as well. The high number of current mathematics professors who are scheduled to retire in the next ten years contributes to this trend.

Additional motivating factors for curriculum review include new breakthroughs in mathematical research and new applications of mathematics. Mathematical research is uncovering links, not only between disparate areas of mathematics, but also between mathematics and other disciplines. These new advances in mathematics and mathematical applications challenge mathematics educators to keep current, which is not something that we have been perceived as doing very well. In a survey conducted by Garfunkel and Young [2], departments outside mathematics were asked why they were teaching courses with mathematical content as opposed to having their majors take mathematics courses for this knowledge. The responses overwhelmingly indicated that faculty in other disciplines believe that mathematics faculty do not know, nor do they appreciate, applications of mathematics in those disciplines. Consequently, while mathematical research is opening doors to other disciplines, unless these applications are included in mathematics courses, mathematics faculty will abdicate this responsibility to faculty in other disciplines and will forfeit the opportunity to show the beauty and appropriateness of the applications of mathematics to these other disciplines.

Teaching problem solving, including the ability to represent problem situations in a mathematical language that permits quick solutions, is a strength of many mathematics programs. However, there is much debate as to whether the inclusion of technology adds or detracts from that strength. With increased accessibility and with price becoming less of a constraint, computers will soon be ubiquitous. New computer related technologies allow more to be done in the classroom and, with current computing capability, there is an opportunity to ask relevant questions which could not be answered previously. Additionally, technology has provided new opportunities for interactive learning. The use of computers in the classroom has been welcomed by students, many of whom have grown up in a technologically sophisticated environment. However, research must be done to assess what students are learning, as well as what skills are being forfeited by this paradigm shift. Is it simply a matter of shifting students from 'What formula do I use?' to 'What button do I push?' Currently, mathematics faculty may be in a transitional stage in teaching mathematics where it is not yet recognized how to use technology to yield additional time to work on problem solving and understanding of basic mathematical theory. In fact, some professors believe the use of technology is creating a dependence on technology that is detrimental to students' understanding of important mathematics. The challenge in making changes for the mathematics major in 2010 is to develop a curriculum that will prepare students for a technologically sophisticated workplace while maintaining the strengths of current programs.

Another issue which we must address is the ever-changing way that students best learn. Today's students have grown up playing video games and utilizing electronic learning devices. They have watched educational programs on television, many of which are quite entertaining.

Consequently, students expect to be dazzled and entertained by their teachers and often express frustration when their teacher does not convey a high level of enthusiasm. Simply stated, these students want learning to be fun. The paradigm of the teacher at the chalkboard while the students listen (passively and attentively) is quickly fading. Now, the challenge to be faced is engaging our students in active learning. Toward this end, many teachers are incorporating undergraduate research projects, group learning, computational modeling, simulation, and visualization into their curriculums.

In the near future, distance learning will be common and will compete with on-site instruction. Colleges and universities must be able to justify their cost and find, as well as be able to articulate, their niche in competing with this low cost option. On a positive note, distance learning offers a wealth of opportunities to enhance the traditional classroom and to offer experiences which would otherwise be unavailable to students. For example, distance learning offers students the possibility of more convenient one-on-one interaction with the teacher. Many teachers are holding on-line office hours, and consequently, commuting students do not have to travel to have access to their professor. Also, through video conferencing, students and teachers can have access to experts in particular areas or can meet with other learners from across the country.

Input from our constituents:

Recently, Chadick and Serio surveyed over 500 MAA Liaisons from nine sections of the MAA. There were 140 surveys completed and returned. This survey of MAA representatives revealed a desire to keep several courses that have traditionally been a part of the mathematics curriculum. The liaisons surveyed felt strongly that the calculus sequence was a critical part of the curriculum. The respondents also expressed a preference that linear algebra, modern algebra, and a junior or senior level analysis course also be retained. While indicating that these courses were necessary in the curriculum, many expressed a need for these courses to be taught in new ways using technology or experimental teaching methods.

The Mathematics Department at Northwestern State University recently invited some of its graduates to campus to give input on needed changes in the mathematics curriculum. There were less than twenty graduates participating. Some of these mathematics graduates working in non-academic environments expressed strong feelings for the inclusion of courses in computer science and statistics in the mathematics major. Many of these graduates were using statistics and computers in their workplaces. Also, among those at the meeting, there was a sense that the mathematics major was intended to prepare students for graduate school even though only a small number of graduates were choosing to pursue further graduate work. These responses indicate a need for multiple tracks within the mathematics major. For instance, there could be a track for students who are planning to work in a non-academic environment, a track for students who intend further graduate work, and a track for students who plan to teach mathematics at the elementary or secondary level. In this regard, several departments with such tracks are expressing satisfaction with this approach. However, this task will be much more daunting for smaller

mathematics departments which are limited by the size of the faculty and the available number of courses.

As a participant in the panel discussion, Andrew Sterrett shared information from his perspective as the author of a book on careers in mathematics [5]. He offered what he considered to be needed changes for the mathematics major. Among his suggestions for mathematics programs were: (1) a few courses in computer science, (2) a year-long sequence in mathematical probability and statistics, (3) a course including model building, (4) opportunities for students to participate in group projects, (5) courses in communication skills, both written and oral, (6) a minor in a field where mathematics is used, (7) a course in simulation, and (8) a senior research project which includes an internship with a company. He also discussed career options for mathematics majors. Among the companies he cited which desire to hire mathematics majors were accounting firms, high tech companies, government agencies, large banks, and airlines.

There are other stakeholders with a vested interest in the needs of mathematics majors who should also be contacted for their input. These stakeholders include employers of mathematics graduates, leaders of graduate programs in mathematics, and leaders in other disciplines in which mathematics majors continue their education.

Conclusions:

In closing, there are many curricular issues in the area of teaching mathematics which must be researched and addressed. We hope that we have helped to articulate some of the concerns as well as begun a dialogue which will identify other important issues. In identifying some of the forces driving change, we offer the following list of experiences and skills which we believe must be incorporated into the mathematics curriculum for students in the year 2010.

- Experience in Undergraduate Research
- Experience in Making Presentations
- Experience in Working in Teams
- Experience in Working on Major 'Real-Life' Projects
- Experience in Data Collection and Data Presentation
- Experience in Mathematical Modeling, Discrete Mathematics, and/or Statistics
- A Solid Knowledge Base in How Mathematics is Involved in Other Disciplines
- Internships
- Communication Skills (oral and written)
- Computer Skills
- Problem Solving and Reasoning Skills

References:

[1] John A. Dossey, *Confronting the Core Curriculum,* Proceedings of West Point Core Curriculum Conference, 1998

[2] Garfunkel & Young, *Mathematics Outside of Mathematics Departments*, Notices of the AMS, Volume 37, #4

[3] Garfunkel & Young, *The Sky is Falling*, Notices of the AMS, Volume 45, #2

[4] Les Krantz, *Jobs Rated Almanac*, VHPS/St. Martin's Press, 1999

[5] Andrew Sterrett, *101 Careers in Mathematics*, MAA, 1996

[6] Robin Wilson, *The Remaking of Math*, Chronicle of Higher Education, 1/7/00