Graduation Address[1]

Department of Mathematics and Statistics

University of New Mexico

May 16th, 2014

Good afternoon everyone. I want to start by congratulating each and every one of the students graduating today. Although I don't know you personally, over the last thirty years I have been privileged to witness the intellectual growth and development of many students just like you.

You should be particularly proud that your undergraduate degree is in the Mathematical Sciences: whether your focus is in Pure Mathematics, Computational and Applied Mathematics, Statistics, or Mathematics Education.

Most Math professors are savvy enough not to let freshman undergraduates in on their big secret: Math is by far the hardest major. Apart from the fact we'd never get any students to teach, the reason we don't spill the beans is that we also know that mathematics is beautiful. Beautiful to behold, beautiful to create, beautiful to share, beautiful because it can be applied in so many different fields. We want people like you to experience this beauty for yourself, and to get hooked on math!

Mathematics is beautiful because it at its core it is the study of patterns and structures.

We start to learn about patterns in elementary school—number patterns like 2,4,6,8, and geometric patterns like a grid of hexagons that tile a room. Patterns like these play a major role in higher level math. But you can also think of the statement of a mathematical theorem as being a pattern. The *If A Then B* logical construct in a theorem tell us that whenever we encounter A we should expect to see B hot on it heels. So the theorem identifies the A-B pattern for us!

Structures, like the structure of a vector space, are abstract mathematical ideas that time and time again we find hiding in concrete applications of math. The power of thinking in terms of these underlying mathematical structures is that if we can identify a pattern in an abstract mathematical structure, then we should expect to find the same pattern in all the different concrete applications that share that structure.

In our math classes patterns and structures rapidly become more and more abstract. The surprising thing is that it is precisely this abstraction or idealization of the material world that gives us the tools to form a deep understanding of the fundamental essence of things. That, by the way, is why math is so hard!

In graduate school I had a professor who moonlighted in comedy clubs. Professor Forman had another take on why math is hard. He explained to me that mathematicians always feel stupid. Before we understand a piece of mathematics we feel stupid because we feel we are not clever enough to work out what is going on. We struggle for hours, days, or even years trying to solve a problem. One day we finally work it out. For about two hours we are on Cloud Nine. So we take a walk in the park to rejoice in our brilliant insights. But the longer we walk the more stupid we feel,

[1] By John Zweck

because we gradually realize that the solution to the problem is so simple we should have known it all along. How could we be so stupid not to see the solution straight away? I have this experience every time I do math. My graduate student had it this week. Let's have a show of hands: How many people here have had a similar experience?

So mathematics is a challenging field to work in. But I reckon that many of you have faced other sorts of challenges on your journey to graduation. These are challenges that we as faculty are often only vaguely aware of. So can you please stand up if any of the following applies to you. Once you're up, stay standing until I get to the end of my list:

1. Stand up if you are the first in your family to graduate from university.
2. Stand up if you transferred to UNM from a Community College.
3. Stand up if you worked part time or full time during your time at UNM.
4. Stand up if you provided essential support to your family or friends during your education. Here I'm thinking of those of you who are the parents of young children or who help look after a family member or friend.
5. Next, stand up if at some point you came close to giving up on your goal of obtaining a degree in math, stat, or math ed.
6. Finally, stand up if you are the family member or friend of someone who is already standing.

OK. Let's give everyone standing a huge round of applause. You have all worked really hard to be here today: both the graduates and their families and friends.

Thank you. Now you can all sit down again.

And while we're at it, let's thank all the teachers and professors from kindergarten to grad school who inspired you to stick with it, who shared the beauty of math with you, and who facilitated your learning experiences. Congratulations to you too!

So why did we all stick with math? For some of us the beauty of math is enough. Some of us love math because it's a fun game. Whatever your reason, let me reassure you that from a purely professional perspective you made a great choice. Each year, the job search website Career Cast publishes a list of the 10 Best Jobs. Careers are rated based on the working environment, average income, outlook for the future, and stress level. This year the number one job on the Career Cast list was Mathematician. Statistician was number three and Actuary number four. This is a far cry from the situation when I graduated in 1988, or even in the early 2000's during the height of the dot com bubble.

How did the mathematical sciences grab three of the top four spots? What's changed in the last decade? Why is this happening now, just at the time you are graduating?

I think that what has changed is that we have now crossed a threshold where the synergy between the mathematical and computational sciences is so strong that mathematical and statistical methods are now routinely used to help scientists, engineers, and policy makers tackle the most challenging problems of our time.

Incidentally, much of the success of this revolution is due to mathematical software like MATLAB, which many of you have probably used in your classes. What you may not realize is that MATLAB was invented right here at UNM by Cleve Moler who wanted to help UNM students just like you do math on a computer.

Put very simply, mathematical scientists have the best jobs because Math + Computers = New Knowledge.

To give you an idea of what I'm talking about, I know of mathematicians, statisticians, or mathematics educators who are collaborating with scientists, engineers or medical researchers to tackle the following challenging problems. Maybe you can see yourself working in one of these fields!

1. Discovering the genetic basis for diseases using bioinformatics.
2. Designing new drugs with the aid of computer simulations.
3. Designing clinical trials to evaluate whether a new drug really does what its supposed to.
4. Understanding the structure and function of the human brain, especially as it is impacted by conditions such as Alzheimer's disease and Schizophrenia.
5. Predicting the weather next week and modeling climate change over the next century.
6. Managing financial risk and investment portfolios
7. Optimizing transportation networks, such as the scheduling of airline flights and the distribution of goods and services.
8. Developing new energy resources: both oil and gas and green technologies like solar and wind power.
9. Designing engineering systems from modern aircraft, to optical fiber communications systems that form the backbone of the internet, to biomedical devices such as an artificial pancreas that automatically controls the delivery of insulin to people with diabetes.
10. Developing methods to analyze the ”big data” sets generated by scientific, engineering, and business applications.
11. Designing algorithms for computer graphics and computer animation that are used in the entertainment industry, in education, and for visualizing large complex data sets.
12. Contributing to the new ”The Science of Learning” and helping classroom teachers at all levels understand how to apply this new knowledge in their classrooms.
13. Working hard to increase the pipeline of students who have a strong mathematical training, an interest in applications problems, and superior communications skills.
14. Promoting learning and working environments that help to diversify the mathematical workforce.
15. And finally, communicating the societal importance of mathematics to the public, both in the schools and through science journalism.

You know, that's just a small sample. There are lots of problems that are not quite so high profile but that are still important and that can profit from the perspective and skills of mathematically trained people like yourselves.

It is because we can help tackle problems like these that being a mathematician is the best job in the world!

Some of you may choose careers that don't use mathematics on a regular basis. That's fine. In fact its really great, because math gives you the critical thinking skills that are so much in demand in so many professions. For example, just this week I read about the experience of Bethany McLean, a Williams College math major who became a journalist and was the first to report on the Enron fraud. In an article in the Notices of the American Mathematical Society this month she is quoted as saying:

> I gave a talk a few years ago entitled "Why math made me a better journalist". Part of my argument was that math taught me inescapable logic. I am not naturally a tough, confrontational person. But when A doesn't lead to B, I dig in. I can't get around it any more than I could skip a step in a proof. That's made me ask questions until I get answers.

It's the insistence on asking questions until we finally understand what's going on that is the hallmark of someone who has a mathematical training.

OK. So what about me you ask? I want a great career in math. How can I do that? I don't know anything about any of those application areas you just mentioned. Hey, I don't even really understand how math can be used to tackle them. That's perfectly OK and completely normal. I was completely in the dark when I started out too.

Do you know where I started trying to work on applied problems? Right here in the Computer Science Department at UNM. Let me tell you the story. In 1998, I had a job at a university in Reno Nevada. My fiance, Sue Minkoff, was working in the Mathematics Group at Sandia National Labs here in Albuquerque. Since we wanted to be together, I stopped doing pure math, and tried to find someone in Albuquerque who would pay me to use math to do something they cared about. Fortunately, Professor Lance Williams in the Computer Science department here at UNM had some funding and wanted someone who could help him use math to understand how the human visual system worked. I didn't know anything about human vision. Neither did I know anything about the sort of math he needed. In some sense all I knew was some Calculus, Linear Algebra, Differential Equations and Analysis. But I had a pretty good general education in mathematics and to enlarge my mathematical tool kit I came over to the Math Dept where Dr. Pereyra taught me about Wavelets and Dr. Sulsky taught me how to solve differential equations using a computer. That was enough to get me started.

The experience with Lance taught me three things about working on applied projects: (1) A mathematical training gives you the toolkit and modes of thinking that allow you to work on almost any problem that is quantitative in nature; (2) To succeed you need to work with experts in the field who really understand the application; and (3) It is always the mathematician's responsibility to learn the application and to find ways to effectively communicate mathematical ideas and results to their collaborators.

Since then I have worked on several other projects that involve Math +. Math + Optics, Math + Trace Gas Sensors, Math + Brain Imaging, Math + Plasmas. In each case, I've had the privilege of learning the + field by collaborating with very accomplished scientists and engineers. In each case, I've also had to significantly expand my mathematical toolkit to tackle the problems they posed.

Earlier this year, Professor Mac Hyman from Tulane University spoke to the SIAM Student Chapter at my institution. For many years Professor Hyman led the Mathematical Modeling and Analysis Group up the road from here at Los Alamos. Part of his job at Los Alamos was to run a summer internship program for math majors. He recruited as many star math undergrads as he could as well as many average students. After several years, he decided to find out what sorts of career paths his student interns had followed. What he found was very interesting. Some of the average students had gone on to spectacular careers in the mathematical sciences, whereas some of the star interns didn't do nearly so well. By interviewing his former interns, Dr Hyman discovered that to have a great career you need to do three things right:

1. You need to work on the right problem;
2. You need to do it in the right way; and
3. You need to do it in the right place and the right time.

By the right problem, he meant choose to work on an application of mathematics that you are really passionate about, something like one of the challenging problems I listed before.

By doing it in the right way, he meant find a way to tackle the problem that makes use of a natural talent you have. Use the opportunity the problem provides to build your talent into a real strength, so that you are the best person in your group, or maybe even the best person in the world at what you do.

By doing it in the right place and time, he meant find an engaging environment in which to work. In other words, find great people to work with. The right people are your greatest asset in shaping your career. In fact, my wife, Sue Minkoff, who is also a mathematician often says that picking the right person to work with is much more important than picking the right problem. Sue had a great mentor and because of her experience she is passionate about helping others develop their careers. One of the ways she does this is by editing a column on careers in SIAM News. Take a look for yourself: The articles are both inspiring and thought provoking.

To finish up, I want to tell you a story that illustrates how Professor Hyman's advice to do three things right can lead to a great career. About 8 years ago, while I was still at UMBC in Maryland, I started a collaboration with a Statistician, Anindya Roy, that involved a combination of statistics and differential geometry. In a nut shell the problem was to do statistics in situations where the statistical samples lie on a curved space, like the surface of the earth, rather than in a flat space like the real line.

Justin Jacobs, the student we got to work on the problem, had a background in both math and stat, which made him an ideal choice. Neverthless, I had to teach Justin and Anindya some differential geometry and they had to teach me some Bayesian statistics. Soon after Justin started making real progress he and his wife had a baby. Because you don't get paid very much as a graduate student, Justin's wife told him he had to get a real job. Justin ended up getting a full time job just down the road from UMBC at the National Security Agency. Although, he couldn't tell us much about what he was doing there, he did tell us that some of the problems he was working on involved using ideas from his PhD research project. There were multiple occasions when we didn't hear from Justin for months. He literally disappeared. We found this very frustrating and all but gave up hope that he would ever finish his PhD research. Now, he is finally graduating.

A couple of months ago Anindya and I got a big surprise. We learned that President Obama was about to present Justin with a PECASE Award for his work at the NSA. That's a Presidential Early Career Award for Scientists and Engineers. Wow! It turns out that Justin was working on the right problem, in the right way, in the right place and time. At the NSA Justin joined a group of statisticians working on geolocation problems. Their job was to use mathematical and statistical algorithms to track down bad guys (think terrorists and drug smugglers) and bad stuff (think emissions leaks from nuclear storage facilities). Justin combined his passion for helping his country, with his talents for statistics, numerical analysis and geometry in the engaging professional environment at NSA. His work sent him to 33 countries where he would sit in huts running his computer code to track down the bad guys. Justin told us that at least three stories broke into the news due to his work. Back when he started working with us I would never have guessed Justin would have such a great career. You can tell I'm really proud of him.

FInally, back to you. Today your parents, family, friends and professors are really proud of you. As you go out into the world, I encourage you to find great people to work with who will help you develop your talents into strengths that you can apply to tackle the important problems you are passionate about. Stay in touch with your fellow students who will inspire you and with your professors who will be inspired by the novel ways you will use your degree in the mathematical sciences.

Congratulations! Hat's off to you!