The Best Jobs of the 21st Century?
Mathematicians and STEM Careers

Handout[1] for the talk by Michael Dorff
from Brigham Young University and MAA President-Elect
in Session S092 at the 44th AMATYC Annual Conference, Nov. 16, 2018

Careers for mathematics majors

In 2008, I began running a "Careers in Math" speaker series geared toward mathematics majors at BYU. For this series, the math department brings in about eight speakers who have a strong background in mathematics and who can show how mathematics can be used outside of academia. The idea is to show students that mathematics is used in many careers and that having a strong mathematics background is beneficial in these careers. Speakers have come from various companies, such as Google, Microsoft, Goldman Sachs, Raytheon, Lawrence Livermore Labs, Sandia Labs, Capital One, Lincoln Labs, Centers for Disease Control and Prevention, Epic, Pharsight Pharmaceuticals, Bell Helicopter, Ford Motor Co., Nike, the National Security Agency, the Department of Defense, and Homeland Security. Let us describe some of these careers in general categories.

Data analyst/analytics consultant: Data science deals with analyzing extremely large amounts of data. Think of all the data being created on the internet. In 2011, it was estimated that the Library of Congress had collected about 235 terabytes of data. A few years later, Google estimated that the internet holds about 5,000,000 terabytes of data—20,000 times as much as the Library of Congress. And it is growing. The are many career opportunities for people who have experience in collecting and sifting through large amounts of data in order to analyze it and determine patterns. By large amounts of data, we mean quantities so large that they could not possibly be put into a spreadsheet and examined a person.

In the PIC Math program, students work on problems coming directly from industry. In just the first three years of PIC Math, students worked on over 100 problems from industry, and about 80% of these problems were data science problems. This makes sense, since most companies and government organizations have troves of data, and many of them don't know what to do with it. A good example of this comes from Tom Wakefield, who directed a PIC Math group at Youngstown State University. Youngstown, Ohio has seen a dramatic decline in its city population and a shift in the location of the population over the past forty years. However, the police department was still using a division of the city into police beats that was created decades ago. Students received 2014 crime data from the police department, analyzed the data, and proposed two new models for more equitable divisions of the city into police beats. The police department adopted one of the proposed models.

It is not hard to find other examples of how companies have used data analytics to improve their products and services. For instance, Google has used data analytics to improve its internet searching techniques, Netflix has used data science to provide users with recommended new movies based upon a user's ratings of previously watched movies (see the "Netflix Prize"), Nike has used

[1]This is an excerpt from an upcoming book *A Mathematician's Practical Guide to Mentoring Undergraduate Research* by Michael Dorff, Allison Henrich, and Lara Pudwell, to be published by MAA and CUR

data analytics to make marketing decisions about their sports apparel, and sports teams from basketball to football use it to improve their chances of winning (as in the movie *Moneyball*).

Software engineer: Programming or coding is an essential skill for any mathematics student who wants a career in industry or business since there are many companies from small start-ups to large international companies that are constantly in need of programmers. Companies that hire mathematics students as programmers include large tech firms such as Amazon, Microsoft, and Google, in addition to lesser known companies like Epic (which creates software for medical records at hospitals and clinics) and FAST Enterprises (which provides software and technology consulting services for government agencies). Some people may think that a student should be a computer science major to be a programmer. That may have been true years ago, but in talking with employers and recruiters, we have learned that they are not as interested in what STEM field students major in or even what courses they have taken as they are in what skills the students have. This is an important message to get across to students.

I know of one company that assesses students programming skills not by looking at the students' majors but by giving prospective employees an online programming test. The test consists of a made-up programming language, something that students would not have seen before. The test starts with a list of words, each of which is a specific command in this made-up programming language. The test has a set of questions in which some code in this language is provided, and the examinee is asked to give the output from the code. Next, there is a set of questions in which the examinee is supposed to write code in this made-up language to do specific tasks. This is the coding test the company gives to all prospective software engineers, regardless of what the student's major was or which programming classes the student had taken.

Technology consultant/engineer: Technology and engineering companies such as Raytheon, Boeing, Sandia National Laboratories, Lawrence Livermore National Laboratory, Bell Helicopter, Ford Motor Company, and W. L. Gore (manufacturing) employ many mathematicians. In the past, if students wanted to work for companies that specialize in developing engineering projects, they often needed to be engineering majors. Today, these companies hire a significant number of other STEM majors, including mathematics majors. When I first starting talking with employers, he was intrigued that such companies would employ mathematicians. He had naively thought that they would want to hire only engineers. But one time, he had lunch with some recruiters from an engineering firm and they pointed out that they like to form working groups consisting of people with different backgrounds—engineers, programmers, statisticians, and mathematicians. This allows for different perspectives to be used in solving a problem.

Financial analyst: Financial firms that deal with banking, investing, and trading employ mathematicians. These firms include Goldman Sachs, Capital One, RBS, ING, and Jane Street. In 2017, I took a group of 18 students to Europe for four weeks to visit companies that hire mathematics students. One of the companies the group visited in London was Jane Street, a quantitative financial trading firm. The group's contact was a mathematician working for Jane Street. During the visit, the students learned about what the company does, what financial trading is, and how mathematics is involved. At the end, the group got to play a simple trading simulation game, then they were able to ask questions as they were treated to pizza. In another instance, I attended a STEM career fair and talked to a representative at RBS, the royal Bank of Scotland. The RBS representative mentioned that they hired mathematics majors for their number sense and for their ability to pay attention to detail.

Operations researcher. Operations research applies analytical and mathematical methods to

help make better decisions. It deals with such questions as "What is the optimal way to schedule a set of tasks?" and "What is the most efficient way to arrange the flow of traffic?" Examples include the scheduling of a sport team's games, the restocking of large businesses such as Walmart, the scheduling of surgery in hospitals (i.e., arranging physicians, patients, nurses, and operating rooms), the synchronization of stoplights in a city, the evacuation of a building or a stadium in case of a terrorism threat, and the implementation of efficient delivery routes for UPS or airlines. I met Eric Murphy (PhD in complex analysis) at an AMS regional conference when he was doing operations research for the U.S. government. He was advising the Joint Chiefs of Staff on how to best move supplies and troops in and out of foreign countries. Sommer Gentry does operations research as a research associate for the John Hopkins University School of Medicine while she is a mathematics professor at the US Naval Academy. A few years ago she made national news when she teamed up with her husband, a surgeon, to use operations research to find a more efficient way to match kidney donations with recipients.

Medical scientist. As medical fields become more immersed in data, mathematics can provide more insight in the study of medicine. Helen Moore, who has a Ph.D. in geometric analysis, illustrates one example. Originally, Helen's interest did not lie in the medical field, but after attending some conferences and workshops related to mathematics and medicine, she became interested. Later, she was offered a job with Pharsight (a pharmaceutical company) as a senior scientist. When a pharmaceutical company develops a new drug, they must determine safe and effective dosages to prescribe to patients. Helen used control theory and mathematical modeling to do this. Michael Cannon, a BYU alumnus with a B.S. in mathematics and a Ph.D. in epidemiology, provides another good example. He now works for the Center for Disease Control and Prevention doing research on the prevention of birth defects.

Government agencies and national laboratories. The National Security Agency (NSA) is the largest employer of mathematicians in the United States. They employ mathematicians to work on cryptographic problems, complex algorithms, and data science issues. We know more than a dozen mathematicians who work for the NSA. We also know mathematicians who work for the Census Bureau and for Homeland Security. National laboratories generally hire students with strong mathematics backgrounds. Robert Berry, a former Masters in math student, worked at Sandia National Labs on energy problems. Carol Meyers, who has a B.A. in mathematics and a Ph.D. in operations research, works at Lawrence Livermore National Labs on problems related to nuclear disarmament and emergency disaster preparedness. Emilie Purvine, who has both a B.S. and a Ph.D. in mathematics, works on problems related to cyber security and the power grid at Pacific Northwest National Laboratory.

Computer graphics engineer. Doug Roble at Digital Domain Productions, Inc. has mentioned that mathematics was used in the creation of top money-making movies ranging from *Avatar* to *Toy Story*. Tony DeRose, a research scientist at Pixar Animation Studios, has given talks on how mathematics has changed Hollywood, giving examples of such movies as *The Incredibles*, *Brave*, and *Ratatouille*. Alex McAdams [2] has a Ph.D. in applied mathematics and is a senior software engineer at Walt Disney Animation Studios. He used mathematics to model hair and clothing in such movies as *Frozen* and *Moana*. Ramus Tamstorf, a computer graphics engineer at Walt Disney Animation Studios, and Adam Sidwell, an independent Creature Technical Director, have also voiced this same message of math's importance in movies. They work to make the movement of animated characters, the light shading on characters, the flow of water, and the crashing of objects seem realistic.

There are two important messages I has learned from listening to employers and recruiters. One is that there are many careers available for mathematics students, but students will not find these if they are looking for jobs that advertise for a "mathematician." Instead, students should be looking for jobs that are described with STEM terms such as *analyst, data, technology, consultant, scientist*, and *engineer*. The second message is that students cannot passively go to a job interview thinking they will get an offer just because they are a math major. Instead, they should go to the interview with detailed answers to the questions "Why you should hire me?" and "What I would bring to your company?", and they should answer these questions during the interview, even if they are not asked them. My answers to these questions are given in the next section.

What employers have said about hiring mathematics majors

I have talked with employers and recruiters for about a hundred companies that hire mathematics students and has asked them why they want to hire these students. What would you imagine their response is? This is an important question, so think about it for a moment before you look at the answer. Mathematics majors should also think about the answer to this question since employers will not hire students *just because* they are mathematics majors. Instead, students need to *convince* potential employers to hire them. Employers have said that they want to hire mathematics majors, because of the students'

- problem solving skills,
- ability to abstract,
- attention to detail,
- ability to learn new ideas and concepts on their own,
- ability to break a big problem down into smaller pieces that can be solved separately, and
- different perspective they bring to solving a problem (as compared to people in other fields and disciplines).

Paying attention to detail is a characteristic that people do not think of at first. I know a student who earned an M.S. in mathematics and had interviews with five companies. In three of those interviews, she was asked a question similar to the following: "Suppose you have a clock with an hour hand and a minute hand, and the time was 1:25. What is the angle between the hands?" To answer this, someone would have to know that there are 360 degrees around a circular clock, so each five-minute interval represents 30 degrees. Some people would say that since there are four five-minute intervals between the one and the five on the clock, the answer would be 120 degrees. But that is not correct. Why? Because as the minute hand moves, the hour hand also moves. So at 1:25, the hour hand is not pointing at one but is somewhere between one and two. This is the type of detail that many mathematics majors are good at noticing.

Likewise, offering a different perspective on how to solve a problem is not an attribute that many mathematics students think to mention. Industrial firms and businesses create groups to work on problems. These groups often consist of people with different backgrounds, such as programmers, scientists, engineers, statisticians, and mathematicians. These teams are effective because each person brings a different perspective to solving a problem. It makes sense that the way an engineer approaches a problem is different from the way a mathematician does. Using these different perspectives enables teams to come up with better solutions to problems.

As an aside, a solution to a problem in industry can be very different than a solution to an academic problem. In industry, a team is usually given a problem with a timeline and is told to come up with the best possible solution within that time frame. They are not necessarily looking for an exact answer but the best possible approximation, given the constraints. Once the time period is over, the group will move on to another problem. They do not have the luxury of exploring nooks and crannies of a problem like many of us in academia do, unless getting an optimal solution is a critical part of the group's task.

This list of reasons why employers hire math majors and students with solid math skills is important for students to know because a student on a job interview should be prepared to talk about these reasons. Of course, students shouldn't simply say, "Hire me. I was a math major," and then tick off the list of skills. Instead, a student should go into a job interview and say, "This is what I can bring to your company. I have great problem solving skills. In my math classes, we solved hundreds of problems, and that helped me become a strong problem solver. Let me give you an example... Also, I have demonstrated the ability to methodically approach a big problem by breaking it down into smaller pieces that can be solved separately. When I was a sophomore, I began working with a group of three other students and a professor on a research problem that had never been solved before. This experience taught me how to break a complex problem into smaller pieces, solve each separate piece, and then bring all the pieces together to solve the bigger problem. Let me give you more details..." Talking about the skills in the list above in this way will improve a student's success in a job interview.

Just having the skills mentioned above, though, is often not enough to get a job. When asked about what mathematics majors should do to better prepare for these careers, employers and recruiters have recommended that math students

- know how to code or program,
- develop good communication skills (i.e., speaking and writing),
- have experience working intensively on a hard problem whose solution is unknown (i.e., do an undergraduate research project or a summer internship), and
- have background in some other field (e.g., statistics, computer science, English, biology, economics, etc.).

Knowing how to code is an essential skill for a mathematics student who is interested in a career in industry. If a student does not know how to program, it will be extremely difficult for them to get a mathematics-oriented job. The general consensus from employers is that it is not too important which programming language students know. Instead, they say that having the experience of knowing how to program is what is most significant. If students have that experience, then they can more easily learn whichever programming language that the company needs them to use. Students do not need to take a lot of programming courses, but they must be able to demonstrate their abilities to program.

Good skills in speaking and writing are also important. Often, careers in business and industry require employees to work in groups that try to analyze a situation and find a solution. Good communication skills are critical for success in this team-oriented environment. Also, there may be times when an employee will need to explain a project to a supervisor who has little or no background in mathematics or convince the supervisor that the employee's group is making progress on an important project to which the company should allocate resources. Consider a hypothetical

scenario where an employee is initially asked to give a 30-minute presentation about the project but then, due to unforeseen circumstances, is asked to shorten the presentation to five or ten minutes. A great skill for students to develop is the ability to present the technical ideas of a project in a way that a non-technical person can understand, while being flexible enough to either give the highlights in a short, two-minute elevator speech or expand their presentation to include significant details. For more thoughts on this, see the book *The Persuasive Wizard* [1]. Students often develop these flexible communication skills in an undergraduate research experience since they are typically given many opportunities to explain their research to others, through informal talks, conference presentations, and posters. The MAA's Student Poster Session at the Joint Mathematics Meetings can be an especially useful training stage for such a skill, as some poster session-goers ask students to give very short overviews of their work while others may ask more in-depth questions.

Studying advanced undergraduate mathematics and solving homework problems from a textbook can be difficult, but it takes a different set of skills to work on an open-ended research problem in an undergraduate research setting or in an internship. Such situations require working for long periods of time on a single problem without knowing if a solution is even possible. Often, even if there is a solution, students aren't given many inherent clues on how to obtain that solution. Yet, this situation is a familiar one in industry. In short, skills that students learn by working intensively on a hard problem whose solution is unknown, such as an undergraduate research problem, are great assets for those pursuing careers in industry.

References

[1] F. L. Givens. (2011). *The persuasive wizard: how technical experts sell their ideas to nontechnical decision makers*. CreateSpace Independent Publishing Platform.

[2] PIC Math Industrial Math Case Studies. *Creating More realistic Animation for Movies* featuring Dr. Alex McAdams. `https://www.maa.org/programs/faculty-and-departments/pic-math/solving-real-world-problems`.