and safeguards are put in place, the PhD advisor is destined to remain the central figure in the development of their graduate students.

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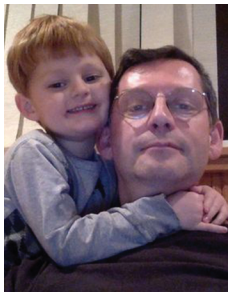

Alex Iosevich

Credits

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Supporting Faculty in Mentoring Students for Careers Beyond Academia

Lee DeVille, Tegan Emerson, Skip Garibaldi, Mary Lynn Reed, Talitha M. Washington, and Suzanne L. Weekes

Career opportunities for mathematicians in business, government, and industry have never been better. At the 2023 Joint Mathematics Meetings in Boston, MA, the AMS Committee on the Profession sponsored a panel entitled "Supporting Faculty in Mentoring Students for Careers Beyond Academia." The goal of the panel was to provide actionable advice for faculty who seek to increase their ability to mentor students in finding nonacademic employment. To enable this information to reach a wider audience, we offer this interview-style report between our moderator and panelists.

The Panel

Reed: *Welcome! I'm happy to be moderating this discussion on behalf of the AMS Committee on the Profession. To kick things off, I'd like each of the panelists to introduce themselves, briefly mentioning what programs/institutions/activities they've been involved with related to mentoring students for nonacademic careers.*

For myself, I spent the majority of my mathematical career in government and industry, including twenty years at the National Security Agency. My last position at NSA was as the chief of the Mathematics Research Group, which included oversight of the mathematics hiring process at NSA. Panelists?

Lee DeVille is a professor of mathematics and the director of undergraduate studies at the University of Illinois at Urbana-Champaign. His email address is rdeville@illinois.edu.

Tegan Emerson is a senior data scientist at the Pacific Northwest National Labs. Her email address is tegan.emerson@pnnl.gov.

Skip Garibaldi is the director of the Center for Communications Research in La Jolla, California. His email address is garibaldi@ccr-lajolla.org.

Mary Lynn Reed is a professor of mathematics at the Rochester Institute of Technology. Her email address is mlrsma@rit.edu.

Talitha M. Washington is a professor of mathematics at Clark Atlanta University and the director of the Atlanta University Center (AUC) Data Science Initiative. Her email address is twashington@aucenter.edu.

Suzanne L. Weekes is the executive director of the Society for Industrial and Applied Mathematics (SIAM) and holds a professorship at Worcester Polytechnic Institute. Her email address is weekes@siam.org.

DOI: https://doi.org/10.1090/noti2784

DeVille: I was one of the co-PIs and directors of the PI4 program (Program for Industrial and Interdisciplinary Internships at Illinois) from 2014–2021, and am now the director of the PhD summer internship program at Institute for Mathematical and Statistical Innovation (IMSI)—both programs are aimed at giving PhD students the training they need to be competitive in nonacademic careers after graduation.

Emerson: I am a senior data scientist and mathematics of data science team leader at Pacific Northwest National Laboratory. I finished my PhD in 2017 and made the transition out of academia directly after my PhD. I hold two joint appointments in the Department of Mathematical Sciences at the University of Texas El Paso and the Department of Mathematics at Colorado State University. Additionally, I am one of the organizers and founders of the Topology, Algebra, and Geometry in Data Science (TAGDS) research community (`www.tagds.com`).

Garibaldi: Out of graduate school, I followed the traditional academic career path from postdocs up through being a full professor. A few years ago, I left academia to work at CCR La Jolla, a math research institute that is part of a nonprofit corporation—the AMS calls it a BEGIN[1] employer. Most of my experience mentoring students was during my time as a professor, where I advised undergraduates and PhD students who were interested in nonacademic careers.

Washington: I am the director of the Atlanta University Center (AUC) Data Science Initiative[2] which supports the development of data science innovations across Clark Atlanta University, Morehouse College, Morehouse School of Medicine, and Spelman College. As data science evolves in the industry space, it is important that our work includes inviting our industry partners to work alongside us to develop data science research, curriculum, and student career pathways. As an applied mathematician, I enjoy the interplay between various sectors to solve problems of societal interest.

Weekes: In graduate school, I spent a summer working at IBM; and at WPI, we've made solid connections to industry via our Center for Industrial Mathematics and Statistics. Our students work on research problems that come directly from our industry partners. That sort of experience (for both students and faculty advisors) has been brought to participants all over the US via the MAA & SIAM PIC Math[3] program. Now, as executive director of the Society for Industrial and Applied Mathematics, this connection between academia and industry is core.

Best Advice

Reed: *What's the best advice you have for faculty on how to mentor students for careers beyond academia?*

DeVille: Let me start by pointing out that it is neither easy nor natural for most academic mathematicians to mentor students for careers beyond academia, because of how we ourselves were trained. I don't mean for this to be daunting—it's more to say that if someone starts in this direction, and finds it difficult going at the beginning—this is completely normal. A key point is that academia and industry are two different worlds: they have different values and different incentives. The types of skills, habits, and values that we want to instill in our students are different based on what their lifepaths will be. For a student going on to an academic career, it makes a lot of sense to think slowly and deeply about a problem to come up with the best possible solution; for a student going toward industry, it can be more important to inculcate breadth and flexibility. Another note: the topic of a student's PhD dissertation is often not directly relevant to a student's career in industry. Most employers who are hiring math PhDs want to know that a student can carry out a major research program; if they're convinced the student cracked a hard abstract problem, they often don't care for the details. So, it happens that a student writes a very "pure math" thesis, but still does well in the nonacademic job market because they have coding skills, soft skills, etc. Also, one last thing: it is probably not necessary for every PhD advisor to be good in this space. A lot of the mentoring in this direction can be done centrally by a small number of faculty (e.g., by the director of graduate studies or local equivalent, and/or those faculty with existing experience in this area). As long as you have a few strong faculty mentors in your program, you should be fine!

Emerson: One of the most important skills for someone to have at a national lab is being able to create a narrative around your work. Challenge your students to explain their approach and the impact at different levels. Incorporate literature reviews and analysis for students as part of their learning experience to quickly assess the quality of work being done and learn how to reproduce results. Finally, outside of academia you rarely work alone—being a part of a team is really important. Have students work in groups and learn how to handle the types of conflicts that arise.

Garibaldi: Encourage students to learn diverse subjects. And connect them with resources to prepare for job interviews—SIAM has online videos about interviewing and your campus' Career Center may offer practice interviews.

Washington: One technique I like to utilize is to apply project management techniques within the framework of a course. This includes not only working in teams

[1] *BEGIN stands for "Business, Entrepreneurship, Government, Industry, and Nonprofit."*
[2] `https://datascience.aucenter.edu/`
[3] `https://www.maa.org/programs-and-communities/professional-development/pic-math`

but also talking about the stages of team formation developed in the mid-1960s by Bruce W. Tuckman to optimize team functionalities. I also intentionally expose students to aspects of professional development in the context of a course. This includes creating a resume, writing a personal introduction, and developing SMART (Specific, Measurable, Achievable, Relevant, and Time-Bound) goals. This allows me to get to know the students better and in turn, this helps students better define their mathematical trajectory. In my current role, we have opportunities to engage with data science professionals and we provide guidance on how to network. Incorporating team work along with professional development as a part of the mathematical pursuit is beneficial since it is such an important part of every workplace.

Weekes: I would add that it is important to encourage your students to pursue internships or to get experience with industry. You don't need to have hands-on experience yourself with this. Your university's career services are able to provide help in searching and preparing for internships. Also, direct students to resources from our professional societies about careers; SIAM's career resources[4] are wonderful. Make sure you take a look at our careers brochure.[5] The BIG Math Network[6] is an excellent joint effort with the mission to promote careers in business, industry and government to students and departments of the mathematical sciences.

Common Mistakes

Reed: *Are there things you'd like to advise faculty to avoid doing to best support their students interested in nonacademic careers? What are some common mistakes people make in advising mathematicians seeking nonacademic careers?*

DeVille: I think the biggest mistake I see both faculty mentors and students make is assuming that industry is the "backup plan"; that the "best" students go on to postdocs and industry is for the ones who "don't make the cut"—and a corollary of this is that getting a nonacademic job is somehow easier. This is a prejudice that is widely held in academia, and especially in mathematics, in my experience. One main problem is that many mentors and students have the mindset that a PhD student should focus on writing a strong thesis, and then maybe throw in some coding in year five, and it will all work out. This is not true—students need to train for their desired career throughout the PhD, and this training should be integrated with their education throughout.

Emerson: I echo many of the sentiments of the other panelists. Encourage coding early, on real data, to keep their options open. Don't only value becoming the world expert in a very niche topic. Many careers outside of academia, I believe, are served by a "the more you know" attitude. A broad base builds the best foundation, in my opinion, for a career beyond academia where flexibility and curiosity are necessary for longevity.

Garibaldi: I assume no one reading this article would denigrate the choice to pursue nonacademic careers. Still, the very nature of how math departments operate enforces the idea that the people doing mathematics are professors of mathematics. This message is often transmitted by the learning materials we provide ("here, read this math paper" written by a math professor) and by telling students to attend seminars (typically given by professors from math departments). We would better support our students interested in nonacademic careers by also exhibiting nonacademic mathematical careers as relevant to math.

Washington: When assigning group work, provide guidance on how to work in a group. There are models, such as Tuckman's Model [Tuc65] that can easily be incorporated into the class discussion so students understand how to participate effectively in a team. I have also found that by defining and assigning each student a role on the team (lead, recorder, questioner, timekeeper, etc.) we help students take agency in ways they not have otherwise. Having high expectations while also giving students the tools they need, both mathematical and social, better positions students to learn and excel.

Weekes: I hear of faculty who discourage their students from taking internships as it takes them away from their PhD program. I don't think that this is fair to the students. New PhDs are not obliged to become university faculty as their advisors are, and faculty should respect and support students' career goals.

Programming and Data Science

Reed: *How do you view computing/programming in conjunction with preparation for nonacademic careers? What about statistics and data science?*

DeVille: The ability to code is crucial for a student looking to pursue a research industry career, and it is important for a student to have a record of this (gold standard: a GitHub that solves some interesting problems!). That being said, I don't think it is necessary for mathematics PhD programs to revamp their PhD curriculum or courses to include coding—many campuses have courses or bootcamps in a variety of languages and contexts, not to mention coding contests, etc. So, motivated students can learn in this area, but outside of your department. For data science, as for coding, there are many resources and opportunities outside of math. (Of course, if a PhD program is able and willing to include coding and data science in their PhD training, that is great! But it is not strictly necessary.) I think it's also worth pointing out here that one

[4] https://www.siam.org/careers/resources
[5] https://www.siam.org/students-education/programs-initiatives/thinking-of-a-career-in-applied-mathematics
[6] https://bigmathnetwork.org/

thing a student can do during the PhD that will really make their applications more competitive after graduation is an internship (typically during the summer). A successful internship (or even better, multiple ones) is one sign to a potential employer that a student will be able to fit well into their environment—and typically gives a student one or more valuable letters and references for the job search. Students who are interested in industry should be strongly encouraged to pursue such internships. One worry I have heard from faculty is that a student's dissertation research will go more slowly if they are gone for the summer. I find that often enough this isn't the case—a student who works on something completely different for a while comes back to their original problem refreshed and ready to make progress, whereas students who don't do a second project can often become discouraged and despondent if all they ever do is bump their heads into the same brick wall over and over...

Emerson: Use real world data sets! Have them struggle with "data wrangling" a bit so they get a sense of how real-world problem solving begins. Also, encourage students to prepare presentations with no equations. They should be able to describe what they did and why it matters.

Garibaldi: Include coding and data science organically in the classes you teach. For example, when you teach a class in pure mathematics, there are typically homework exercises that amount to a hand computation. Replacing one of those with a somewhat larger version is often an easy way to create an entry-level use-a-computer-to-do-real-math kind of homework problem.

Washington: Coding nowadays is not limited to one language. Our students are entering a workplace, both inside and outside of the academy, where there may be a high expectation to be able to code in different languages. I enjoy providing opportunities for students to develop programming skills. When I taught Calculus III, I utilized MATLAB to create the 3-dimensional visualizations. I first did a hands-on, follow along where I engaged the class in walking through how to code on MATLAB. Then, each homework assignment included an exercise on creating a visualization in MATLAB. Throughout the course, I did embed coding and found it to be a fruitful experience as students found interesting ways to create the plots. In my current role as Director of the AUC Data Science Initiative, we provide opportunities for all faculty and staff to upskill in data science and coding and have over 200 participate in our summer workshops. I am seeing coding become a meaningful skill across the curriculum from public administration to chemistry to social work and mathematics, just to name a few. Having students experience coding in different disciplines, I think, will position students well for the technology-driven future they will enter.

Weekes: Every student—at the very least every math student—should get experience programming. Basic statistics knowledge via a formal class or in the process of a research experience is also important.

Building Networks with Industry

Reed: *What advice do you have for faculty on how to build networks with industry? Are there specific conferences we should go to? How do we meet people in industry, and what can we do to keep lines of communication open to be able to get information we should share with our students?*

DeVille: Probably, the most valuable connection is through alumni networks. Keep track of what your PhD alumni do and encourage current students to get in touch with them. Alumni who are working at (or, even better, recruiting for) an academic employer are the absolutely best resource for students looking for a job in a closely-related industry. Departments can also have career days where they invite alumni to speak and give feedback to students (many organizations like their employees to do this—if they're happy with someone, they always want more candidates just like that person!). Also, don't forget your department's undergraduate alumni; many employers looking for mathematics BS graduates are also looking for mathematics PhD graduates. Admittedly, alumni networks suffer from a "chicken and egg" problem—what if you don't yet have a robust alumni network in your program? If your institution has an engineering school, this can be a valuable resource—many of the same employers who would hire an EE PhD would hire a Math PhD. More generally, most campuses have career centers and will have a lot of contacts at STEM-hiring outfits.

The communication (both up- and down-stream) can be a challenge. One system which seems to work is if there is a faculty member in charge of all of this (networking, establishing recruiting events, etc.). In many departments this is also handled by the director of graduate studies, or local equivalent. But be forewarned—this is in itself a full-time job, and it is important that departments recognize and reward this work.

Emerson: SIAM conferences are a great place to interface with industrial mathematicians. NeurIPS (Conference on Neural Information Processing) is also a major event that draws a mix of mathematically-oriented academics and industry researchers. TAG-DS (Topology, Algebra, and Geometry in Data Science) is a scientific research community led by researchers at national labs and faculty at universities. There are a series of TAG-DS conferences and workshops at top data science events that facilitate networking between academic, industrial, and government researchers.

Garibaldi: First step is to use the contacts you already have. Your department has alumni working at companies.

Talk to them! Most people are flattered when someone else takes an interest in what they are doing and wants to learn from what they have learned. You can ask industry folks to give talks to your students. And if they do, faculty can attend! The information from the presentation is ore to be mined for mentoring next year's students, who may not benefit from getting to hear the same talk themselves.

Also, when you hear someone in industry talk about the scientific or technical challenges they face, it is natural to listen like a mathematician who wants to solve their problem and focus on the technical details of the problem. But for mentoring, it is better to pull back your focus and think also about the person and how they are describing their challenges, the words they are using, and what that context says about their greater view of the technical landscape. Later on, when talking to students about careers in industry, you will have a better sense about how people in that industry view their world.

Washington: I have built many networks with those in industry via LinkedIn. This is a great way to network with industry folks and as well as alumni. Some LinkedIn tips: include an e-mail address that works, a profile that is updated and matches the resume, and a customized URL. When engaging with industry, it's important to get the industry representatives to engage with faculty, not just students. The industry partners will be eager to recruit students for jobs but they need to remember that the students come and go but faculty stay, and can influence many different student cohorts over their careers. If our faculty understand the expectations from industry about what content knowledge would position students for success in these constantly evolving workspaces, this would provide an opportunity to spice up a course and connect student learning to future opportunities. I really enjoyed attending UIDP's events[7] because they focus on strengthening university-industry partnerships through engagement, research, and other synergies. As we move forward with the AUC Data Science Initiative, we are working to strengthen our relationship with our sponsors to build out data science with our faculty to create more robust pathways for our students.

Weekes: Set up an industry advisory board at your department level. Alumni connections are also very useful. Have university staff contact alumni and ask if they would like to visit campus, give a talk, meet with students.

New Opportunities

Reed: *In your experience, how is non-academic mathematical work changing? Are there new opportunities in this area, or other information, you'd like to make faculty aware of?*

Emerson: Research in data science is changing very fast. The timescales are changing. Outside of academia if an idea is going to fail, you want it to fail fast. This concept is somewhat at odds with the inherently rigorous nature of mathematics and can be a challenge for students fresh out of mathematics graduate programs.

Garibaldi: Do your students include their GitHub on their resumes when they are applying for jobs? Lots of people do these days, and that is a new thing to me.

Washington: Many companies and nonprofits need technology development but some may have limited budgets to carry out this work. This is where those in academia can provide insight and also engage in fun problems. The AUC Data Science Initiative is partnering with the AUC police chiefs and the Atlanta police to find data-driven solutions to enhance public safety in our neighborhoods. I am really excited about this project because of the value added to the community. By looking both at the university or college and nearby enterprises, one may be able to find some interesting mathematical and data science challenges that could provide great learning experiences for students while providing societal benefits.

Weekes: Faculty and students should join a professional society and read the news and newsletters that come out from these organizations. This is a way that they can stay updated on the latest and greatest. I mentioned some resources earlier and would add to that SIAM News.[8]

ACKNOWLEDGMENTS. A special thanks to the rest of the AMS Committee on the Profession JMM 2023 Panel Subcommittee, for their assistance in organizing this panel. Specifically, thanks to Christian Borg (University of California Berkeley), Jim L. Brown (Occidental College), Ellen Eischen (University of Oregon), and Pamela E. Harris (University of Wisconsin Milwaukee).

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Credits

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Leaving Academia

Karen Saxe

Some academic friends tell me that my career path has been "alternative." In fact, it was all but that for most of my career.

I completed my PhD; enjoyed a two-year post-doc; then settled down for 28 years of teaching and leadership at one institution. At all points in that 30-year run, everything seemed "conventional," if extremely fortunate. I appreciate that it is hard to land jobs in academia that are as satisfying and wonderful as mine have been. I am still surprised that I was able to raise three children, stay married, sustain meaningful friendships outside of math, get tenure, be promoted to professor, and become department chair. In retrospect, I've succeeded in achieving my graduate school hopes. But it was hard: I worked nonstop at my job and struggled to be a good mom. I know many of you are familiar with working all day, then heading home to prepare dinner; spending the evening with your family until the kids go to bed, then working again from 10 p.m. until midnight (or as long as you can manage to stay up writing lectures, grading, and answering emails).

The career I have now began in 2013, when I served as the AMS Congressional Fellow. During the academic year 2013–14, I worked for Senator Al Franken in his Washington, DC, office. I worked on education policy concerns: to establish a national STEM master teacher corps, to provide education stability for youth in foster care, to strengthen connections between community colleges and local industries, and to improve the net price calculator that higher education institutions must make publicly available. I also had the opportunity to support Franken's work on the Senate Indian Affairs Committee.

One part of that position that I really enjoyed was the writing. It was mostly of two kinds: (1) background materials for committee hearings, which included providing suggestions for questioning witnesses, or (2) drafting speeches. These speeches were, typically, ones the senator would give when visiting a high school. After that year, I returned to my academic job and, honestly, had no idea I would end up back in Washington! Then in 2015, I learned that Sam Rankin, my predecessor at the American Mathematical Society, was planning to retire. Now here was a job I wanted! I began full time with the AMS in January 2017 as director of government relations. I did not apply for this position because I was trying to leave my academic

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DOI: https://doi.org/10.1090/noti2785