The BIG Newsletter

Volume 19, Issue 1, Spring 2023

Business, Industry, and Government Special Interest Group of the Mathematical Association of America

In this issue:

Getting ready for MathFest 2023

As we are getting ready for the MathFest, August 2-5, 2023 in Tampa, FL, we have two announcements to make regarding the contributed session and a panel session related to BIG SIGMAA activities.

Call for abstracts for contributed session *Mathematical Experiences and Projects in Business, Industry, and Government.*

The extraordinary growth of complex open-ended problems facing business, industry, and government, along with the flood of available information and data to address these challenges, may seem overwhelming. It should not! As mathematicians, operations research analysts, and engineers, including those within academia who have addressed these issues, we experience and tackle these problems with experience, knowledge, and technological tools. We solve applied mathematics problems in business, industry, and government, including military applications, almost daily. We seek presenters to share their real world applied examples of this type of problem-solving. These talks may include successful mathematical applications or problems where you have no clue how to proceed and are seeking ideas from our audience. Your talks will serve as inspiration to solve and tackle the real challenges that we may face in the future. You do not have to be a BIG SIGMAA member to attend or present. The deadline for submission is April 30, 2023 and early submissions are encouraged.

Abstract Submission Link:
https://forms.gle/95MWG23HM2AUqZ7m9

Panelists wanted: BIG SIGMAA is co-organizing a career panel “Career Paths in Business, Industry, and Government." We are looking for panelists. Please email cmaherboulis@leeuniversity.edu if you are interested. Also, plan to attend and direct your students to the panel as appropriate.

Interviews with Guillermo Alvarez Pardo and his students Carson Dorough and Tate Pflum

Guillermo Alvarez Pardo finished his BS in Mathematics at the Complutense University of Madrid, Spain, and finished his MS in Mathematics at The University of Manchester, United Kingdom, with specialty in Applied Math. In Mexico, he worked for some of the finest universities, including UNAM, ITAM and Tec of Monterrey, where he completed an MBA. He has experience as a consultant, project manager and business advisor. He currently works as a full-time math professor at Cuesta College, in San Luis Obispo, California, where he has served as the Mathematics Innovator in the NSF-awarded IUSE program. He has also led the PIC Math Program 2021-22. He is the developer, coordinator and instructor of *Math 290: Introduction to Research,* a CURE (Course-based Undergraduate Research Experience) launched in Fall 2021. He or his Math 290 students have presented their work at local, national and international events like IEEE ISEC (Laurel, MD, 2023), MathFest (Philadelphia, PA, 2022), IUSE Summit (Washington, DC, 2022), CMC^3 (Monterey, CA, 2022), Cal Poly Research Symposium (San Luis Obispo, CA, 2022), AMATYC's Annual Conference (Toronto, Canada, 2022, and Phoenix, AZ, 2021), and NCUR (2022 and scheduled for 2023, Eau Clair, WI).

What attracted you to the PIC Math program?

I was working as the Math Innovator in an IUSE (Institutionalizing Undergraduate STEM Education) project (NSF grant: 1821351) intended to bring undergraduate research (UR) opportunities for students. My research showed that students would be more interested in those opportunities if they were part of a course that they could enroll and get credit for what is commonly called a CURE. That was the inception of *Math 290: Introduction to Research*. Since many of our students in math courses are not math majors, I thought I needed open problems that could engage students from business, engineering, physics, marketing… and certainly mathematics. I learned of the PIC Math Program, with its concept of *industrial partner* and *industrial problem*, and it promised to be a strong ally and an exciting experience. I thought I had to bring it to Cuesta College and integrate it into Math 290.

Can you tell us more about Math 290 and how the integration of the PIC Math Program into the CURE worked out?

Sure. *Math 290: Intro to Research* is a simple 1-unit problem-solving course. We found it convenient to make it a short-term 12-week course, with students meeting the instructor once a week. During the first three or four weeks, students are given training on the basics of research: structure of a report or paper, academic search engines, use of LaTeX, professional associations, paths to publication or dissemination… Then they are put in teams and given problems to work on. Part of the differentiator of our Math 290 course is that these are actual open problems, so the solution is unknown to students and to the scientific or industrial community alike. This is what I call the *hard definition* of UR.

Here is where the PIC Math Program played out very well. Following its methodology, I managed to gain the collaboration of the Department of Public Works (DPW) in San Luis Obispo, California, which provided a very nice problem about the trash collection system in downtown. The DPW was our *industrial partner*. Students worked on this industrial problem for eight weeks, with weekly tasks assigned according to their expertise. They also worked on pure math problems taken from *The College Mathematics Journal*, by the MAA. By the end of the course, they had written a nice report for the DPW and the PIC Math Program and had also sent a solution to one of those pure math problems to *The College Mathematics Journal*.

After the course was over, three of the most proactive students presented their work with both problems (the industrial and the pure math) at NCUR 2022 in two different abstracts that got selected. Two other students presented their work with the industrial problem at MathFest 2022, as part of the PIC Math Program exhibition in Philadelphia, Pennsylvania. These two students also presented their work at a Cal Poly Research Symposium in San Luis Obispo, California. The solution sent to *The College Mathematics Journal* was judged valid by the referees and the student's name and affiliation got published as solvers in the April 2022 issue of the journal. This dual value proposition, with the industrial and pure math problems, proved to be very effective at taking the best from and giving the best to students.

Can you tell us about some highlights or main features of your PIC Math experience? How many times did you run it? How many students were involved?

I ran it for only a year, in the 2021-22 edition. Unfortunately, there have not been more editions so far. Seven students participated, working on the industrial problem in two teams. At the beginning, the teams were competing for bringing great solutions to the same questions, and in the last weeks they joined forces to work together (although with division of labor) in the final questions and the elaboration of the report.

In addition to the results mentioned above, a highlight of the experience, both for Math 290 and the PIC Math Program, was the diversity of backgrounds that were engaged. Among the seven students, there were two women, two first generation college students, one first generation American student, one student from another 4-year educative center and one dual-enrollment student from a local high school, with ages ranging from 17 to 35 and majors including Math, Business, Aerospace Engineering, Civil Engineering and Psychology (plus the high school student).

What would you recommend to other faculty who want to incorporate similar experiences into their school's curriculum?

I recommend them to take initiative and try one way or another. The perspective of developing a new course can be intimidating, specially because it requires quite a bit of college-wide support. However, it is not that difficult once you know the steps, and the college would easily support it once they see the fruits it can bring. You can contact me if further orientation is needed. The benefits of UR for students and for faculty are widely discussed in the literature, and I can say that it is all very fun.

If you don't think that a new CURE is a feasible course of action in your situation, you can always try to integrate the experiences into one of your already existing courses. You can also bring a program like the PIC Math, the LSAMP, the NREUP… There are various nice options.

What did your students do after finishing Math 290 and the PIC Math? Did the experience affect their careers?

I cannot answer that thoroughly. I should send them a follow-up survey to see where they are after a year of finishing the experience. What I do know is that at least four of the seven Math 290-PIC students were accepted into Cal Poly within 8 months of finishing the course. I also know that one of them thanked me during the presentation in Philadelphia for he was attending job interviews and, in the last one, the interviewers had asked him extensively about his participation in the solving of the industrial problem and his future presentation at MathFest, and they were very pleased to hear what he was telling them.

What piece of advice would you give a student who isn't sure of what they want to do yet?

Keep looking and try to offer your value in different places. You might find a place where they are sure they want you there.

What would you recommend math professors to do so that they prepare their students well for a career in the BIG sector?

Developing courses or programs like Math 290, PIC Math, LSAMP or NREUP is a great option. Incidentally, we have also gotten a LSAMP grant at Cuesta and we are now trying to develop a new course on Data Science, potentially as part of a Data Science program.

In general, I have found that you can develop a good deal of maturity in students, while also having them excited about the BIG connections, by using student discussions in which students have to work with an article from a newspaper or journal, or with a video or lesson by another author, or a documentary, and answer specific questions, making sure that they use in their answers the vocabulary and concepts studied during the chapter.

What would you say is the most important skill that one needs to work in the BIG?

Initiative. You have to be proactive at developing new skills and putting the ones you already have at the service of others' missions or your own. Staying hungry and hustling is usually key.

Anything else that you may feel like important that was not covered above?

I wrote a paper with info and stats about my experience of two years with *Math 290: Introduction to Research*, including the PIC Math Program. I presented it at *IEEE ISEC* on March 11, 2023, at Johns Hopkins University in Laurel, Maryland. The paper should be soon available at *IEEE Xplore* under the title of *Successful Model for a Course-based Undergraduate Research Experience (CURE) in Mathematics and STEM during the First Two Years of College*. I encourage everybody to read the paper for more detailed explanations.

Carson Dorough is a sophomore physics major. He is a tutor and absolutely loves phrases such as "here's a better way to remember this" or "this is why this works". He has just finished taking the mathematical research methods course and was kind enough to answer several questions for the BIG SIGMAA Newsletter.

What attracted you to take *Math 290: Introduction to Research*? I find math interesting and wanted to be exposed to more of it.

What project(s) have you worked on? I worked on some questions from math journals designed to give undergrad math students a challenge. One question involved a straightedge and compass construction, the other was algebraic.

Can you briefly describe how you approached the project? I've found that when I want to solve a math problem, often it's really about how long you spend delving into it. The longer I spend trying new attempts, the more familiar I get with the problem and I discover new ways to attempt to solve it until the right answer pops out.

What do you find to be the main highlights or benefits of the experience provided by Math 290? Gaining access to the problems in the journals was awesome. I've never had the opportunity to solve a construction problem or find an innovative solution to an algebra question, and I'm not going to forget what I learned.

How has your attitude towards math changed as a result of this project? I still enjoy it, and now I have had experience understanding what it takes to solve really abstract problems.

How have your plans for the future changed as a result of this project? They have not. I still plan on finishing my bachelors in Physics, and then getting a masters in physics or something else that's just as awesome. When I transfer to a university, I'm very excited to try math classes in Abstract Algebra or Topology.

Tate Pflum is a sophomore at Cuesta College with a major in Political Science. He is interested in law. He was kind enough to answer several questions for the BIG SIGMAA Newsletter.

What attracted you to take *Math 290: Introduction to Research*?
What first attracted me to take *Math 290: Introduction to Research* was that I was contacted by my statistics professor to see if I wanted to join. I saw it as a special opportunity, and I decided to take it to broaden my horizons in college.

What project(s) have you worked on?
The project I worked on in Math 290 was about the benefits and effects a food truck would have on the Campus of Cuesta College.

Can you briefly describe how you approached the project(s)? I approached this project in a more legal way, looking at regulations and fees that would have to be completed before a food truck could perform business.

What do you find to be the main highlights or benefits of the experience provided by Math 290?
The highlights and benefits of the experience provided by Math 290 was the opportunity to work with my peers and learn how to more effectively research topics you are working on.

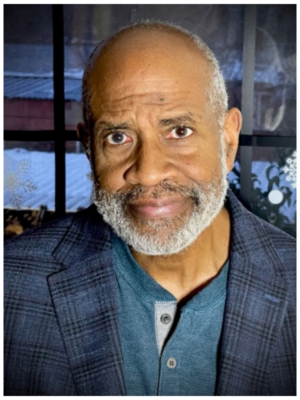
How has your attitude towards math changed as a result of this project?
My attitude toward math has not changed as a result of this project as math has been one of my favorite subjects and this class only supported my opinion about math.

How have your plans for the future changed as a result of this project?
My plans for the future have not changed as a result of this project, but have made me consider changing majors to a more business related one.

What are your plans now? My plans now are to continue my education and apply to a four-year university to earn my bachelor's degree in either political science or a business major.

Anything else you would like to express? I would like to express how much my professor helped me during this class and how supportive he was as well. Thank you professor Alvarez for this time at Cuesta College.

Interview with Lloyd Douglas



Lloyd E. Douglas is an independent consultant. A Certified Research Administrator, he is the former Associate Director, Office of Contracts and Grants at the University of North Carolina at Greensboro. Before going to UNCG, he was Assistant to the Vice President for Research at the University of Nevada, Reno. He is a former first vice-president of the MAA and has served as its Governor-at-Large for Mathematicians in Business, Industry and Government as well as a member of its Distinguished Lecture Series committee. He is also a former chair of its Committee on Minority Participation in Mathematics and its former Interim Director of Programs. From 1984 to 2008, he worked at the NSF and while there oversaw a large increase in the REU program in the Division of Mathematical Sciences. He also managed the Mathematical Sciences Postdoctoral Fellowships, served on the coordinating committee for NSF's CAREER program and co-chaired the implementation committee for the NSF's ADVANCE program. He received NSF's Meritorious Service Award in 2007. He is a co-Principal Investigator on MAA's National Research Experience for Undergraduates Program, whose goal is to support the participation of mathematics undergraduates from underrepresented groups.

What do you see as the biggest difference between working at the university, working for the NSF or working as an independent consultant? I think that the differences among types of employment or even individual jobs tend to be cultural. Adapting to different cultures may even be the most difficult part of learning a job. Otherwise, I think that there are more similarities than one might think. I've worked at four universities, and I found that working at NSF was very similar. I've also worked at other Federal agencies both civilian and military and I found that they were very different than working at NSF, even though they were all Federal agencies. I think the reason for the similarity is that a large number of NSF staff have worked at universities. The big difference of working as an independent consultant, of course, is that you don't have a boss. It also means that you have to find your own work or vice versa.

What would you recommend math professors to do so that they prepare their students well for their careers in BIG? A big start is to not treat careers in BIG as failures for those who don't get academic jobs. Not all of this is done intentionally but some is. One of the questions that I've asked math professors is: If you view that your job as a faculty member is to produce your replacements, in a 40-year career how many students do you need to do that in order for you to be successful? I argue that the answer to that question is: one. Even if you are a very small liberal arts college, I'm pretty sure that in a 40-year career you will have more than one student. So, what are the rest of them supposed to do? We all believe that math is important, no matter what you do, so we should act that way and train mathematicians to go into every endeavor.

What would you say is the most important skill that one needs to work in the BIG? Caring. I think it's important to care about things beyond yourself. Far too often I've heard people say "I'm the first…" or "I'm the only…". Nobody else really cares about that. I think that who you are is a lot less important than what you do. Very few of us will be remembered in history, no matter how important or significant we think we are. The impact of what we do, however, can last for a very long time and have multiple ripple effects. So, we should make sure that we are doing things that are beneficial to others rather than detrimental.

What would you recommend students do to be competitive for jobs in BIG? My advice would be to make yourself valuable, whatever that takes. It's a lot easier to have people see value in you than to try to sell yourself. Be that person who is willing to do what others won't. Learn as much as you can, even if you don't see an immediate use for it. Be curious and generally interested in things. What do you do if this isn't your nature? Learn it! I've been told that all two-year-olds are naturally curious, so if you've lost this, try and get it back. It's in you.

What piece of advice would you give a student who isn't sure of what they want to do yet? After multiple careers and being retired twice, I'm still not sure what I want to do. This isn't a bad thing. Keep your options open. I can't even tell you the number of things I said that I would never do but ended up doing. You don't really know what you are going to like or dislike until you do it. Ask anybody how they ended up in the profession that they did, and I'd bet that most of them didn't have that as a childhood goal. Also, people change careers. Not getting it "right" the first time isn't a failure. Sometimes people even benefit from having multiple careers.

What would you recommend to professors who want to work in the government sector like NSF for a while? Do it! Many of the permanent NSF staff started out as professors who decided to try working at NSF for a while and ended up liking it so much that they stayed there. It isn't for everybody but if the opportunity presents itself, I'd suggest giving it a try. And no, you don't have to be a full professor before working at NSF.

Anything else that you may feel like important that was not covered above? One thing that you may never see in a job description although it's very important is "plays nicely with others." It's something that we're supposed to learn as children, but many seem to lose as we become more competitive, trying to set ourselves apart from others. I think it's important to realize that life is not a zero-sum game. When you work well with people it opens up more opportunities for yourself. So, ironically, looking out for others can make things better for you.

Interview with Justin Gilmer

Recently, Justin Gilmer, a researcher in Google's Brain Team, made a break-through progress on the Frankl's union-closed conjecture https://gowers.wordpress.com/2016/01/21/frankls-union-closed-conjecture-a-possible-polymath-project/ . The conjecture states that if a family of sets is union-closed (the union of sets A and B is in the family whenever A and B are), there must be at least one element that appears in at least half the sets. For a long time, the conjecture resisted mathematicians' attacks. Dr. Gilmer himself tried to tackle it for quite a time as a PhD student at Rutgers University. Then, years later while working in machine learning, Dr. Gilmer cleverly applied tools from information theory to give the conjecture a first serious crack. More progress by other mathematicians quickly followed. Dr. Gilmer was kind enough to answer our questions for the newsletter.

Can you tell us more about your background and how you became interested in math? I've always loved mathematics. In first grade after learning long division I would divide very large numbers by 7 just to see what happened. Math in middle school was not as fun, but it got exciting for me again when I learned calculus and started doing math competitions. At that point I was fairly sure I wanted to major in math.

Did you have any idea of what you wanted to do when you were an undergraduate? Long term, no. I knew I enjoyed math so choosing that as my major was an easy decision. I also took some computer science because I found that interesting as well. Graduate school for math seemed also like the obvious choice, though I took a year off to teach English in China (back in 2009).

How did you become interested in the union-closed conjecture? I learned about it in graduate school and it quickly became one of my favorite problems to think about. I didn't spend a ton of time on it because I knew it was notorious. It was always more of a hobby interest, a fun problem to think about, say on walks or while I'm falling asleep.

After getting your PhD, why did you choose a career in the industry rather than in academia? It was a tough decision. Ultimately industry seemed like the safer choice. Academia is incredibly competitive if you want a research focused position, and it wasn't clear that if I went that path that I could end up in a place I'd be happy with. Perhaps the main reason is I knew I didn't want to teach full time. I would say my utility function was u(tenure track) = u(industry) + epsilon >> u(teaching position), so the expected value of industry was higher given how uncertain the future looked from doing a postdoc.

How did you learn about the job opportunities out there/how did you come to apply for the job you have? The first few things I tried I didn't particularly like. I first went into data science, I did a data science internship at Merck and then did the Insight data science bootcamp. Turns out I don't particularly like data analysis or even statistics, I far prefer more programming heavy jobs. But even programming full time initially felt quite scary given I only minored in CS back in college. Luckily enough many companies are willing to hire math majors who demonstrate they can learn programming on the job. Doing some side projects and taking online courses helps a lot here.

My first job was at Bloomberg where I joined their machine learning team. I went into machine learning after watching Andrew Ng's Coursera course and doing some side projects. I enjoyed that position quite a bit, but while I was there Google announced the Google Brain residency program and I ended up joining the first cohort. For my application I trained a neural network to do next move position and board evaluation for Go. It was fortunate timing because DeepMind announced AlphaGo shortly after I finished that project (the project is still viewable on https://github.com/jmgilmer/GoCNN). One thing to note about that project, it was something I built after working professionally as an ML engineer for a year, there is no way I had the ability to do it during my PhD (I just don't want to scare away anyone in case it looks intimidating). I've been a researcher at Google ever since.

Can you tell us about your work in Google's Brain team? I debug neural network training failures. Some engineer is training a giant, 300 billion parameter model. The training loss smoothly goes down for the first 1 million steps of training until suddenly BOOM it takes a bad step, the loss jumps and the model becomes useless. Why do these failures occur, how do we diagnose them and how do we correct them? To answer these questions, my collaborators and I plot lots of metrics about the training dynamics like gradient norms, loss curvature, and specifics of the internal activations within the model to get a sense of what goes wrong within the model. We read theoretical work about training dynamics, but this is more to build intuition. Making actionable changes to models unfortunately requires some guesswork and careful empirical measurements.

Working for Google is a dream of many mathematics students. What would you recommend them to do to be competitive for these kinds of jobs? My job is very unique, I'm a machine learning researcher and most of my coworkers have PhD's in machine learning. Getting a research position in machine learning is incredibly difficult and a number of very fortunate things needed to happen for me to get to where I am. If you want to do ML the best thing is to show interest via side projects, but still getting to a research position is really hard but you can apply to some industry residency programs like I did. I think that if I couldn't do research in ML, I'd consider being a (C/C++) developer---I particularly enjoyed that style of programming when I was at Bloomberg.

What piece of advice would you give a student who isn't sure of what they want to do yet? Just try many things, until you find something that sticks. Don't expect to love your first job if you leave academia, it may take some time to find what you enjoy.

What would you recommend math professors to do so that they prepare their students well for a career like yours? Allow some time for students to do some non-math/programming projects while they are getting their PhD. Upload these projects to github so companies can see you know how to code and have an interest.

What would you say is the most important skill that one needs to work in your job? Be able to think like a scientist (which I have found is a bit different than thinking like a mathematician). Theory does have some value in deep learning, but oftentimes proving a theorem about how neural networks train requires making so many simplifying assumptions that it has little to say about models people actually use. To do research in a way that has a direct impact on applied work, it's more about testing hypotheses about how these systems work and performing empirical measurements to gather data. My work is more about building an intuitive mental model of these systems that makes testable predictions and is (hopefully) somewhat correlated with the truth.

Interview with Laura Taalman

Dr. Laura Taalman is the director of the [JMU Experimental Mathematics Lab]() (the "JEM Lab"), a collaborative space with a wide range of 3D printing technologies that supports early exploratory undergraduate research in computational and experimental mathematics. The JEM Lab has provided hands-on opportunities for undergraduate and faculty research, and is now a member of Geometry Labs United, a consortium of research labs at national and international research universities. She is also the founder of the JMU 3SPACE 3D printing classroom, and has spent time working for various 3D printing companies. She was kind enough to answer our questions and share her experience with the BIG SIGMAA community.

How did you start with 3D printing? I got involved with 3D printing in 2013 because I wanted to create specific physical conformations of mathematical knots. That semester I ran an independent study course for math majors who were also interested in 3D printing, and taught myself how to create 3D-printable models with various types of software. The technology was exciting and student interest was very high, so by early that summer I had hired two student lab techs and secured an old storage room in the department, which we converted into a small 3D printing lab we called the JMU Math MakerLab (now the JEM Lab). Over that same summer I pitched an idea to the college dean for a 3D printing classroom that all JMU students could take design classes in, and got funding from the college to convert an old chemistry classroom into the first 3D printing general education classroom in the country, called JMU 3SPACE, which started offering classes by the following spring. The 3SPACE classroom is now run by a team at JMU Libraries, while I am still the director of the JEM Lab. Over this same time I made a lot of my work public as I was learning, with blog posts and many design uploads to Thingiverse.

What is Thingiverse? Thingiverse is a community 3D model sharing website. People all over the world upload their digital 3D models to Thingiverse so that other people can download and 3D print their designs, or even remix their designs into new things. For people just getting started with 3D printing the first step is usually to find things to 3D print from Thingiverse, before they figure out how to create their own designs with software.

What 3D printing companies did you work with? In 2015 I worked with MakerBot in Brooklyn, NY as a Senior Product Manager for Education, working with the Thingiverse team within the Digital Products division. In 2016 I did extensive consulting work for Ultimaker and Shapeways.

How was your experience? I found working in industry to be a much different experience than working in academia, and I really enjoyed it. In academia we are often our own islands, each doing a similar type of teaching/research/service dance. But in industry I was part of a team of many dozens of people who were all doing *different* interlocking things, for one combined goal. Of course in industry that goal is ultimately to make the company money, which is something we like to pretend we aren't doing in academia, and the company goals are set from above instead of something we each controlled individually. Aside from that it was great to be part of a giant machine that created new physical and digital products and delivered to deadline. I also had to learn a lot of new things to navigate the job (starting even with really basic things like “what is a product manager?” and “what does Q3 stand for”), which I really enjoyed. It was also amazing to work all day in the tornado of a giant open office with company deadlines to meet, but then to go home and not have to work all night or over weekends as I typically do in academia.

How was your typical working day? At MakerBot we generally worked 9-6 every day, in a giant open warehouse with hundreds of desks and different departments (engineering, website, support, etc) in different parts of the floor. Only the VP types had offices with doors. My work was pretty independent and I had to communicate between a lot of different stakeholders about how best to create and maintain education initiatives on Thingiverse. I worked with the Thingiverse web team but was kind of separate from the team. My daily activities included spinning up new ideas for engaging the education community, putting on my “mathgrrl” designer hat for events like Maker Faire, producing content to help increase the design skills of our users, and liaising with sales or marketing in the corporate building across town. A good part of my job consisted of figuring out how to leverage what physical and digital assets the company already had in order to best support and attract K12 and university educators both online and in the classroom. There were a lot of meetings, PowerPoints, and business jargon on the sales/marketing side and a lot of scrum and standup and product backlog meetings with the software team. The company was kind of in turmoil that year and there were two different new CEOs and three rounds of massive layoffs within the space of 2015 (I made it through the first two, but not the third!). As for math, I didn’t use it very often in that particular job. However, I used my *professor* skills every day. My speaking and confident communication skills came in handy when we had to give quarterly presentations, and my academic training gave me the ability to rapidly learn and synthesize large quantities of information and then find relevant connections and solutions.

What would you recommend students do to be competitive for similar jobs? I highly recommend doing some consulting or internship work if you can; anything that gives you a connection to industry and helps you learn the language and tools of the job that you want. In some cases you can also get a lot of mileage out of knowing something about a company’s products as a power user, or even doing your own independent work and sharing it online. For example, when I applied to work at MakerBot everyone there already knew who I was because of the extensive amount of work I had published on Thingiverse. That was a huge advantage for getting the job, networking across different teams, and most importantly having a deep knowledge of Thingiverse and the needs and experiences of users on the platform. Having said that, having at least some programming experience is incredibly helpful for almost everything you might want to do in the tech space.

What piece of advice would you give a student who isn't sure of what they want to do yet? Do what you love at work and in your hobby time, and pursue your interests. Keep leveling up in whatever direction makes you the most happy and you will figure it out along the way. None of us know all of the opportunities that are out there, so just work a little every day to open new doors and move forward. You don’t need to know the end point, and decisions you make don’t have to be permanent. Just figure out what’s “next” and keep doing that.

What would you recommend math professors to do so that they prepare their students well for a career in industry? The ability to work with others and communicate and document their work would be the at the top of my list of things that math professors can help students develop.

What would you recommend to other professors who want to work in the industry for a while? I recommend confidence. It isn't going to seem like you are qualified to apply for any job, but you can find ways to use your academic experience and skills to convince a company to hire you if you find the right people to talk to (sometimes even if a job isn't posted already). Everyone will think you are smart because you are a professor, although if you are a woman I can sadly report that many people will ask you "what grade did you teach" (ouch). I would also recommend being prepared for volatility. In some industries things move very quickly, and that includes people moving in and out of jobs, being laid off, suddenly having a new supervisor or CEO, etc.

What would you say is the most important skill that one needs to work in the industry? The confidence that you belong there (even if you have to fake it!), and the ability to advocate for yourself and your projects with managers and other teams.

The Pre-History of the Mathematics Research Department at AT&T Bell Labs

By Greg Coxson

A century ago, the Bell System was a ``hot-bed of industrial mathematics''. You don't hear that phrase often, do you? I would like to convince you that it is apropos. At the time, the Bell System was not yet the juggernaut it became later in the 20th century, when anti-monopoly forces in the government moved to break it up. It was striving aggressively to expand its network of telephone line across the nation. This required innovations in many areas, including signal transmission through metal wires and cables. Inevitably, this called for individuals with mathematical abilities and training.

By a sequence of events, its technical staff at AT&T in the 1910s came to include four mathematicians who would support, define, and advocate for, something called industrial mathematics, in the process creating, in stages, the singular Mathematics Research department at Bell Labs. That department employed, among others, such ground-breakers as Richard Hamming (1915-1998), creator of Error-Correcting Coding Theory; Claude Shannon (1916-2001), who created Information Theory; and George Stibitz (1904-1995), one of the fathers of modern digital computers. The names and stories of George Ashley Campbell, John Renshaw Carson, Edith Clarke and Thornton Carle Fry deserve to be better known, especially in BIG SIGMAA.

George Ashley Campbell

The first of the four to join AT&T was George Ashley Campbell (1870-1954). Originally from Minnesota, he earned an undergraduate degree from MIT in 1891, followed by masters degree from Harvard in 1893. This earned him a fellowship to study in Europe. Over the next three years, he enjoyed what seems like the dream late-19th-century Applied Math Grand Tour: one year of study in each of Vienna (with Ludwig Boltzmann), Gottingen (with Felix Klein), Paris (with Henri Poincare).

In 1897, when Campbell joined AT&T, it was expanding, and desperate to achieve longer transmission ranges for its telephone signals. A key to achieving longer ranges was to solve the problem of line capacitance, which resulted in high attenuation, a problem especially in longer transmission lines. A solution was available already, thanks to British engineer Oliver Heaviside (1850-1925). Heaviside's loading-coil invention addressed issues during the costly mid-19th-century trans-Atlantic cable project. It entailed inserting inductive coils at intervals along a line, essentially cancelling out range-limiting capacitance on the line. Here is where Campbell's sojourn in Europe likely helped him become a star right away at AT&T - Heaviside's work was well-known in Europe. Soon after joining AT&T, Campbell built and tested telephone lines imbued with loading coils, leaving him with insights unavailable to anyone else, in particular, practical formulae for optimal spacing of the coils. Loading coils would deliver to AT&T not just a doubling of transmission range, but also savings in materials. One estimate is that by 1924, this single invention saved AT&T $25 million.

In 1899, AT&T assigned a team of patent lawyers to prepare a patent application for the loading coil (Heaviside never patented his invention). What happened next was a shocking failure, but also ultimately an important step toward decades-long top-management support for mathematics at AT&T. Campbell's invention was so mathematically complex, that it caused delay, while the patent lawyers worked to understand the invention. This opened an opportunity for Mihajlo Pupin (1854-1935), a well-connected Serbian-immigrant engineer at Columbia University. Pupin would later claim that the idea came to him while hiking in the Alps. More likely is that Pupin heard of Campbell's impending filing through the grapevine at Columbia University (only blocks from AT&T which had relocated to Manhattan from Boston). Whatever the case, Pupin was granted patent rights for the loading coil and AT&T was not. In fact, AT&T's filing was beaten by a mere two days. To recover the potential benefits of the invention, AT&T bought Pupin's patent rights for what would eventually approach a half million dollars.

George Campbell published ``Mathematics in industrial Research'' in the October 1924 issue of BSTJ. He expanded on the article for a 1928 book of the same title, on the same subject.

John Renshaw Carson

With Campbell's next great invention, the Electric Wave Filter, AT&T was not going to take any chances in the patent process. They hired John Renshaw Carson (1886-1940), a mathematician with a masters degree from Princeton. He grew up in Pittsburgh, the son of a grocer who ran a ``fancy-grocery'' concern. In 1907, he graduated from Princeton alongside his twin brother Joseph Robb Carson. John R. Carson stayed on at Princeton to teach, and ultimately earned a masters degree in Mathematics.

Today Carson is best remembered for single-sideband (or SSB), for which he earned a patent, and for which he developed the mathematics behind Amplitude Modulation, so important in what would soon be the phenomenon of AM radio industry of the 1920s. A well-known photograph of Carson in the company of a large group, including Albert Einstein and Charles Proteus Steinmetz, was taken at a 1921 demonstration in Brunswick, New Jersey. Carson is sometimes mis-identified as Nikola Tesla

in that photo, which is particularly ironic, and frankly unfair, given that the group (including George Ashley Campbell) were on hand to witness Carson's SSB invention enabling wireless communication across the Atlantic Ocean.

Carson was actually hired into the Patent Department, rather than into AT&T's engineering staff. His one assignment was to gain Campbell a patent, by explaining Campbell's mathematics to the patent attorneys. His success on this task resulted not just in a valuable patent for AT&T, but also in what would be decades-long top-level support for mathematics in service of engineering innovation.

Carson worked at AT&T Development and Research until 1934, when the company was merged with Bell Labs. Most of that time he worked in the Transmission Engineering unit. He died unexpectedly in 1940 of a heart attack.

This photograph shows John R Carson just behind Einstein, to the right (viewer's perspective). While Einstein and Steinmetz stand out, it was actually an event in Brunswick NJ in 1921 where John Carson's SSB invention was used for wireless communication across the Atlantic. Note the antenna array above the group. Steinmetz is sometimes identified as the ``first Industrial mathematician'' in America, by Thornton Fry's metric. That is, the individual (1) is employed in industry (Steinmetz was the "Wizard of GE''); (2) is a member of AMS.

Edith Clarke

The 1910s was a time of strong hiring of young technical talent at AT&T, and of something I think was notable, even revolutionary -- the hiring of women to technical

positions. One of those hires, Sallie Eugena Pero (1893-1981), remarked in an article in the July 1922 issue of the Vassar Quarterly, "*You may be interested in a short history of the introduction of college girls into this work, especially since a Vassar graduate was the pioneer. She entered the company to assist the present Research Engineer who, I believe, was first to employ college girls for distinctly mathematical work.*" The "*work*" in question was mathematical work in "telephony"; the “*research engineer*” was almost surely George Ashley Campbell; the “*pioneer*” was Edith Clarke (1883-1959). Campbell was also the one who hired Sallie Pero, in 1915, three years after hiring Clarke.

Clarke began life in Ellicott City, Maryland, one of nine children in a farm family that would experience the loss of both parents when Edith was still in school. The young Edith Clarke struggled with reading, but early on showed remarkable skills in mathematics. One of her favorite pass-times was an especially challenging version of the card game Whist, popular at the time.

With her inheritance from the death of her parents, she decided (against family advice) to bankroll her college education. She was accepted to, and graduated from, Vassar College. After a variety of post-college travel and work experiences, she was hired by AT&T as a computer. Clarke did not intend to stay at AT&T (she was set on traveling the world) but she ended up staying for six years. During that time (often described as during the years of World War I), she organized a unit of computers, mostly young women, within Western Electric, AT&T's manufacturing subsidiary. The role of these computers was to perform computations for the engineers.

Clarke left AT&T in 1918 to pursue graduate studies at MIT. She made history as the first woman to earn an MIT masters degree in Engineering. She also patented a calculation device, taught engineering and wrote a well-regarded textbook, and while working for General Electric, she helped developed the power system for the Hoover Dam project.

Thornton Carle Fry

The photograph shows Thornton Fry overseeing ``computer’’ Jessie Smith (graduate of St Lawrence College) who is operating the Corradi Integraph, by which integrals are computed in tracing out functions.

During the 1910s, AT&T was interested in hires with mathematical skills. Two notable such hires were Sallie Pero and Thornton Carle Fry (1892-1991). Pero, like Clarke, was hired initially as a computer, but was elevated in 1919 to the rank of engineer, unusual for a woman at that time. Thornton Fry can best be described as an industrial mathematics “force of nature”. Author of numerous textbooks, he also wrote about the discipline of industrial mathematics on several occasions. One example is his article “Industrial Mathematics”, which appeared in AT&T's technical publication, Bell System Technical Journal (BSTJ), volume 20, number 3, in July 1941.

Fry came to AT&T with a mathematics degree from Findlay College in Ohio, and some graduate work in Mathematics, Physics and Astronomy at the University of Wisconsin; by 1920 he earned a PhD in Applied Mathematics from the University of Wisconsin.

Fry was also the founder of the afore-mentioned Mathematics Research Department at Bell Labs. For this, he built upon the Edith Clarke's computing unit, elevating it in 1922 into a semi-formal entity included in the company organization charts. He continued a pattern of hiring into the unit graduates of elite women colleges (e.g., Barnard, St. Lawrence, Vassar). The stated mission of the unit was to support the engineering staff with mathematical calculations. For this work, Fry's team of educated women operated precursors to digital computers - mathematical machines with names like the Corradi Integraph, “the Millionaire”, and the “Mercedes”.

In 1928, three years after the formation of Bell Labs, Fry succeeded in making the unit a formal department within Bell Labs, with an annual budget and with Fry as director. Professional mathematicians were hired for the department. Most were male, but there were exceptions (e.g., Marian Gray (1902-1979), a Scottish mathematician who discovered the Gray Graph). The department included within it a unit of female computers. Fry would serve as director of this Mathematics Research department until 1944. A sign of corporate support for the department is that during the Great Depression, not a single mathematician on staff was let go.

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Interested in contributing to the newsletter? Contact Jan Rychtar at rychtarj@vcu.edu

BIG SIGMAA Officers Elections

The current term for the positions of chair, vice chair for programs and secretary-treasurer in BIG SIGMAA will end this year. Members of this SIGMAA are encouraged to volunteer to serve as officers. A Nomination Committee will be appointed by the Executive Committee to solicit suggestions and volunteers for serving as officers from the members of the SIGMAA. The Nomination Committee will then submit their nominations to the current vice chair for services two weeks prior to the deadline specified by the MAA. If you like to serve on the Nomination Committee or suggest a candidate for one of the above positions, please contact the chair, Caroline Maher-Boulis, via email at cmaherboulis@leeuniversity.edu.