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Editorial

Finding Professional Growth and Fulfillment for Early-Career Polymer Scientists and Engineers in Industry

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EDITOR'S NOTE

This Editorial is for informational purposes, sharing personal accounts and experiences of the authors who are academics and researchers in the USA. As a result. the advice and guidance herein come in general from a western perspective, but we hope early career researchers worldwide will find the central themes and advice useful.

1. INTRODUCTION

"Today, polymers are indispensable. The places they show up in our personal lives in items of commercial practice are enormous." This was the introductory quote from Frank Bates, our mutual academic mentor at the University of Minnesota, at a 2016 department-wide general lecture on polymers.[1] The worldwide polymer industry is valued at staggering ∼$500 billion in annual sales,[2] and the second century of polymer science is bringing new opportunities to develop more indispensable commercial applications that address societal needs.[3] And yet, despite the continued centrality of polymers in everyone's lives, what it means to be a professional polymer scientist has undergone rapid and dramatic recent changes that have introduced important questions to ponder in one's early career: where is the potential to further create value from technologically mature commodity plastics? What are the gaps in legacy materials that can be filled by higher-performing, yet still economically viable products? How can we as an industry *realistically* address the continued growth of plastics waste and the dependence of the industry on petroleum-derived resources? How are software-driven tools and digitalization reshaping the R&D process?

In the background of these technical challenges, the early career polymer scientist must also contend with questions related to the business of developing and selling polymer materials. For example, what are the practical realities of a corporate R&D career in the derisked business environment of the post-global-financial-crisis world? What opportunities do startups offer that large companies do not, and vice versa? Indeed, finding a fulfilling career in polymer science is no longer as simple as deciding between academia and industry, and in the case of the latter, no longer defaulting to a single career at one of a handful of large chemical conglomerates, shown illustratively in Figure 1.

Considering these questions that will soon confront many PhD graduates, we write this Editorial to share our personal thoughts and experiences related to navigating our first years in the polymer industry with a western/north American-centric perspective. We will briefly summarize our similar academic backgrounds (grad school followed by postdoc) with emphasis on how we have used each stage to launch into different industrial careers. This will be followed by sections written directly to grad students/postdocs, early career industrial scientists, and academics, to address what we perceive to be important aspects related to the different ways they interact with the chemical industry. At the end of this Editorial, we provide a table with the main points for early career polymer researchers to take away from this, regardless of their geographic location. Our hope is that this Editorial will be a useful resource to students and postdocs entering the job market, and will provoke consideration among current industrial and academic professionals as to how industrial polymer research fits into the broader scientific enterprise.

2. BRIEF BIOGRAPHY OF US

In sections of this Editorial, we will indicate the voice of a particular section by "**Mike**" or "**Jeff**" at the beginning of the paragraph. These brief departures allow us to speak from our own individual experiences, so that similarities and differences can be highlighted more clearly. To begin, we provide a brief background of our current roles at our respective companies and our career paths after obtaining our PhDs.

2.1. Our Elevator Pitch

Jeff: "I am currently a Senior Scientist at Nanite, a venture-backed biotech startup based in Boston, MA. My role in the company is to lead high-throughput synthesis, screening, and development of polymer nanoparticles (PNPs) for next-generation genetic medicines. Nanite focuses on gene delivery and uses AI models to design advanced PNPs for carrying DNA or mRNA to specific destination targets in the body. The most enjoyable part of my job is engaging with an interdisciplinary team of chemists, engineers, biologists, and data scientists. Prior to this, I worked as a Senior Polymer Scientist at 3M in the Corporate Research Materials Lab's Materials Informatics Group. My projects focused on developing innovations in digitizing developmental workflows for machine learning and data-driven analysis of adhesive materials. I received my PhD in

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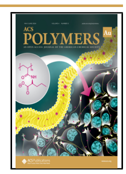

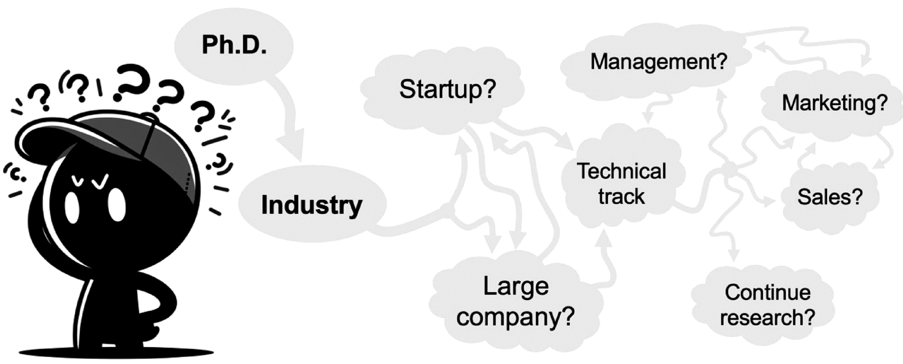

Figure 1. There are many paths to finding a fulfilling career in polymer science in industry. The cartoon on the left was created with Image Creator from Microsoft Designer (www.bing.com/images/create).

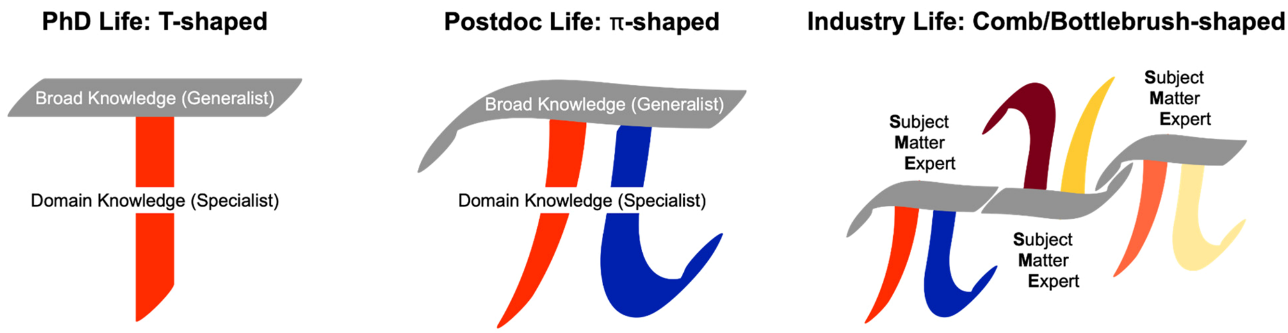

Figure 2. Various stages of gaining T-shaped skills, from a PhD to a postdoc to an industrial scientist. This describes balancing broad knowledge as a generalist with domain knowledge (or multiple domain knowledge) as a specialist. In industry, professional collaboration within teams of subject matter experts (SMEs) enables technical solutions for real world projects.

Chemical Engineering from the University of Minnesota under Frank Bates and Theresa Reineke and worked as a postdoc at The University of Chicago under Matt Tirrell with a fellowship supported by NIST and the Materials Genome Initiative."

Mike: "I am an R&I (Research & Innovation) Scientist in the Composites Strategic Research Group at Syensqo (previously part of the Solvay group). Our team's objective is to develop the next generation of high-performance thermoplastic and thermosetting composites, an exciting area to be in since our materials are currently flying on many different aircraft! Broadly speaking, my job involves developing and testing new resin chemistries that could either unlock new applications for our composites or help make our current processes more effective. Composites is a new field for me—my PhD was with Brent Sumerlin at the University of Florida on controlled radical polymerization and dynamic−covalent materials, and my postdoc was with Frank Bates and Tim Lodge at the University of Minnesota on photoresponsive block polymer-based morphologies. However, I've found that my work at Syensqo still heavily leans on fundamental organic and polymer chemistry. For me, it has been eye-opening to see how corporate research efforts absolutely *must* interface with manufacturing and business functions in order to be successful."

2.2. We both did postdocs before ultimately going into industry—why?

All research careers, not just those in academic settings, now demand transversal knowledge of one's field. A postdoc provides three major benefits to one's industry career: (1) it allows you to establish a second area of expertise to complement the PhD thesis work; (2) it allows you to further practice the ability to quickly get up to speed in a new field; and (3) it is an opportunity to refine leadership and managerial soft skills before they become metrics against which you will be evaluated. A good postdoc is also one of the purest research experiences in one's career—there are no teaching obligations or degree-requirement hoops to jump through. We both agree that our time as postdocs was challenging but one of the most liberating times in our professional careers.

One of the most important things to keep in mind throughout your academic training is that you are preparing yourself for the next job afterward.[4] A useful metaphor is to develop T-shaped strength,[5] illustrated in Figure 2. At the end of a PhD, you become a "T-shaped" person: capable of applying broad, cross-discipline knowledge to open-ended problems while exhibiting expertise in one particular subject matter. You become the subject matter expert (SME) in your doctoral studies. As a postdoc, you become a "π-shaped" person after gaining additional specialties in adjacent fields. For instance, if your PhD focused primarily on advancing polymer chemistry, you may think about learning scattering in a polymer physics lab as a postdoc (we're biased, but it is fun!). Extending this analogy even further for polymer scientists and engineers, we believe that in industry you become a "comb-shaped" person (or in more extreme cases, a "bottlebrush-shaped" person). This is due to the highly team-oriented nature of most industry roles, in which teams of SMEs work closely together to solve technical challenges under certain project constraints of time, capital, or changing market needs. This is useful to think about as a postdoc because your T-shaped skills are what can differentiate yourself from other candidates in the search for the next job. Keep your eyes open for opportunities in leadership development and applying your expertise to emerging global trends.

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3. CAREER OUTLOOK FOR GRAD STUDENTS/POSTDOCS

In a survey of 195 UC Santa Barbara graduate students, a plurality (46%) of respondents reported a preference for nonacademic careers.[6] So if you are a grad student reading this, odds are you are thinking about a career in industry. From our own experience, most grad students lean toward industry careers because they perceive a few common advantages over academic careers: better work−life balance (especially with respect to consistent work hours), higher salaries with more advancement opportunities, higher success rates in interviews, and more flexible prospects for a partner/spouse to find a job if relocation is required. Admittedly, these perceptions are largely correct, and most industrial (and even academic) scientists would agree that it is the case.

However, these advantages are counterbalanced by some disadvantages: less job security (layoffs are always a possibility during downturns, no matter how senior you are), fewer opportunities to conduct pure curiosity-driven research, detachment from your academic network, and fewer mentorship/teaching opportunities. Our goal with this section is to give the proper context of these pros and cons so that you, the grad student reader, can better decide if an industry career is a good fit. We also provide advice on the job search and interviewing process, as these are often the most daunting aspects of going on the industrial job market for the first time.

3.1. What creates success in industry?

A key distinguishing factor of an industry career versus an academic career is the relative abundance of opportunities for promotions or transitions to positions of greater responsibility (and compensation!). As such, potential for career advancement is one of the most important factors to keep in mind when considering different roles, and it cannot necessarily be quantified by a dollar amount. Nearly every new PhD hire will start off as a research scientist and an opportunity to advance to a different role will often present itself after several years of strong performance. If one wishes to stay within the R&D community, this will often be a choice between a management position or a higher-level technical position. But it is not necessarily true that becoming a manager is the way to higher salaries. Many companies have parallel technical and managerial tracks, meaning that the pay scales are comparable as you ascend either ladder. It is a good idea to ask clarifying questions in your interview about how they are structured and key differences between them, such as promotion criteria and timelines, milestones/achievements needed to advance upward, and training/professional development programs that are offered for each track. Many companies also offer flexibility to transition from one track to the other depending on career interests and strengths. It is also worth considering that there are career opportunities in commercial divisions (e.g., product management, market assessment, key customer relations, etc.) as well, even if one starts off in a highly technical R&D role.

Ascending the technical ladder almost universally requires a sustained record of research success that leads to revenue for the company, with greater contributions required to reach higher titles. Early on, you will be expected to successfully shepherd existing projects/ideas, but in order to continue to advance, you need to establish a track record of more independent innovation. Specifically, this kind of success can come in several forms, whether it is filing patents, establishing trade secrets, leading a large capex project, or contributing to a new product launch. At the end of the day, while soft skills and contributions are important, your *tangible* technical accomplishments are your currency as a research scientist. It is therefore well worth your time to develop an "elevator pitch" where you highlight your key contributions to the company. However, it is important to understand both the technical and business value of your projects. Senior management can have varying levels of technical understanding, but they will universally understand financial incentives of a sound business plan. Building an elevator pitch of such a plan involves defining for each project: (1) the people, (2) the opportunity, (3) the context, (4) the technical challenges, and (5) the risk.[7] While it may seem uninteresting, becoming business-savvy enough to translate technical success into monetary value is a highly valued skill in industry.

Developing strong project management skills is *the* key to being successful in industrial R&D. While there is not typically pressure to work long hours, there is pressure to create value with your time. Industrial teams are focused and closely aligned on project goals and deliverables with consistent feedback from project stakeholders. Important questions that you will be regularly challenged with include: What is the definition of "done" for your work? What is needed for the team and project to be successful? What are the rate-limiting steps and constraints in resources? Who can help you quickly resolve project hang-ups? Ultimately your salary needs to be justifiable to the company - they are making a significant investment in you with the goal of eventually recouping it. The quickest path to career advancement in industry is to build a track record of project wins that produce tangible monetary gains over desired time tables for the company.

3.2. How do you get your foot in the door?

If you are familiar with the daunting process of applying to academic jobs, you'll be happy to know that the industry job application process is much more streamlined. Typically you will only need to submit a resume and cover letter for the initial application. That said, there are certain ways to maximize your chances of success. From our experiences, cold applying to open postings has limited levels of success. You need to stand out in screenings from hundreds of applications. Some listings are for internal hires that are only publicly posted for legal reasons, and others are routed to recruiters who may not have the technical background to accurately gauge your competency. Having a referring contact inside the company can greatly increase your odds of moving on to the next stage of an interview. As previously mentioned, for every PhD-level hire, a large U.S. company is typically making a financial gamble that the candidate will pay off for them (this is regionally specific and not general to every position). Furthermore, there is a good deal of pressure on hiring managers to "get it right" when it comes to filling these roles. Candidates who come with internal referrals are known quantities, so managers perceive them as less risky hires. This means that the relationships you build with other researchers, grad students and postdocs throughout your training and beyond are exceptionally valuable, since the majority of them will end up in industry where they could be potential referring contacts. Throughout this process, we encourage you to *remain patient* and *apply broadly*— your first job is usually the hardest one to get.

At this point, we will individually write about our own job search experiences in order to give you a better idea of what you may expect:

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Jeff: "For 3M, I applied to an on-campus 3M rapid recruiting interview at The University of Chicago in 2019 while simultaneously applying for academic jobs. The job posting was generic for PhD level applicants with a background in materials science. I reviewed slides of my PhD and postdoc skills with the STAR method (Situation, Task, Action, Result) and talked to former labmates that interviewed at 3M for advice on interview preparation. A few days after the on-campus interview, I was invited to an on-site interview for a position in a new materials informatics (MI) program in the Corporate Research Lab (CRL). I met with MI Group members with diverse backgrounds in data science, data engineering, chemistry, engineering, and materials science. In many ways, the impressive program resonated with my written faculty research proposal, which described themes of accelerating materials discovery with high-throughput experimentation and controlled polymer synthesis. I received an offer the next day and extended the decision deadline to make an informed decision on pursuing an industrial career or continuing interviewing in the academic job cycle. After considerable self-reflection and conversations with friends and family, I accepted the position of the first experimentalist hired into the 3M MI Group and began plans to relax and travel after my postdoc before a July 2020 start date (these plans, of course, were disrupted by the pandemic).

Working in the CRL MI Group gave me a unique perspective on how bold initiatives are executed in industry. The rhythm and workflow of industry depends on your team. My manager taught me about prioritization and being more cognizant of stakeholders. Outside of work, I was reconnecting with people, including my PhD advisors. I had a remote call with Theresa to catch up on life. One of the things that she brought up was Nanite, a startup company she cofounded that raised a sizable seed round of funding under stealth mode. The value proposition was intriguing, and personally, the mission resonated with what I saw as an opportunity to expand genetic medicine development after the success of mRNA vaccines. I decided to take the leap at the beginning of March 2022 and moved out to Boston that summer."

Mike: "I began my postdoc in January 2020 with all intentions of a faculty career. However, in the aftermath of COVID-related disruptions, I found myself wanting more structure in my day-to-day work life. I felt that an industry career, with a defined management structure and more directed research opportunities, would better offer this than an academic career, where the career trajectory is more nebulous. I started applying for industry jobs in June 2021, and I eventually accepted my position at Syensqo (then Solvay) in October 2022. The interview process was straightforward: it started with a phone call about the position, then I had a screening interview with the hiring manager and a high-level Scientist where I gave a 25 min presentation on my research, and it finally ended with a site interview where I had meetings with various managers and gave an hour-long technical presentation.

I was fortunate to have a stable postdoc position and no family obligations, so my job search was somewhat leisurely: I applied for 8 positions in that time, where 2 were open postings, 3 were via campus recruiting events, and 3 were referrals by a connection within the company. I got no response to my cold applications, was rejected after screening interviews for the campus recruitment events, and got offers from all 3 referred interviews. In fact, I met my current manager in 2014 when I was a senior undergrad and he was a first-year grad student—I never would have guessed at the time that he would end up being a pivotal figure in my career!

It is also worth mentioning that my role at Syensqo is in a totally different field (high-performance composites) from my PhD and postdoc research (chain-growth polymerization chemistry and homopolymer–block polymer phase behavior). Taking this job felt a bit like a gamble, as I had no prior experience before starting the position. But I've been able to rely on the fundamental principles of polymer science to help me quickly learn this new field. In fact, a strong general knowledge of polymer science is one of the best assets you can demonstrate in an interview: while specific experience in the position's field is always valued, managers highly value the ability to relate the technical challenges of a project to its underlying chemistry, physics, and structure–property relationships."

3.3. Practical advice for interviewing

For traditional roles, most large companies will conduct a screening interview (usually ~30 min) either on a university campus or virtually, followed by a site visit interview (whole day) before job offers are made. The screening interview is often an executive overview of your research with a few managers or industrial scientists. The site interview varies depending on the company, but they generally involve meetings with managers and scientists from different teams at the company along with a full 45–60 min technical seminar.

Interviews will typically have a combination of technical and behavioral questions—there are often more behavioral questions that emphasize soft skills than you expect! If you have gotten to a point where you are finishing your PhD, your technical skills are usually not in question; hiring managers instead are often more concerned with how well you work with others and can contribute to a dynamic team culture. Be ready with questions about the position. Authenticity can often be assessed by senior scientists and recruiters. Sample behavioral questions from our experience: (1) "You've been given a check for a billion dollars with no strings attached—what do you do with it?"; (2) "Describe a time you had to navigate a conflict with a coworker and what you did to resolve the conflict."; (3) "Let's say you've come up with an incredible idea that you pitch to management, and they tell you no. What do you do next?" Practice answering these questions and think about why you fit the open position.

As a word of caution, we have seen candidates lose potential offers because they were not sufficiently prepared for their technical seminar. In these instances, candidates did not answer questions in a thoughtful way—that reflected poorly on their ability to bring critical thought to their projects. In industry interviews, you should try to strike a balance in technical presentations: on one hand, the presented work needs to be high level and accessible for attendees without direct experience on the subject to understand, but on the other hand, it also needs to demonstrate mastery of that body of work, especially for the subject matter experts in the audience that may be familiar with the subfield. At the end, consider including a slide that directly maps your professional expertise with specifics about the company. This sets the stage for connecting how your technical skills can fit in with the organization as a whole, as well as for serving as a starting point in the follow-up 1-on-1 interviews with hiring managers and technical scientists/engineers.

At the end of most 1-on-1 interviews, interviewers will almost always ask if you have any questions for them. We recommend planning in advance which questions can lead to conversations

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that simultaneously demonstrate your fit for the role and provide insight into the workplace culture of the team you would be joining. Most interviews will be with different team managers or scientists, so a good general question would be to ask how they would interact with your role. It may also be important to understand if there are different R&D sites and where they are located if you have geographic preferences—this information is not always publicly available. And do not be afraid to ask pointed questions that help you figure out the position's fit with you. For example, if a company has recently undergone a major reorganization or is involved in high-profile events of public interest, it is okay to ask how those may impact your career with the company! At this level, interviews are truly two-way dialogues, and it is critical to establish a mutual fit.

We end this section by highlighting a relatively new tool that can be used for interview preparation: generative artificial intelligence models based on large language models (LLMs). This is best accomplished by prompting LLM-powered chatbots with detailed context to parametrize its responses in subject-matter expertise and domain knowledge. For example, instead of simply asking a question as a prompt (e.g., "What are common interview questions that company X may ask for a PhD polymer science job opening?"), a user can first instruct the chatbot with the complete job description and a summary of their thesis work, followed by generating consecutive interview questions. This can be used to (i) reflect on your own qualifications, skills, and values in relation to the company, (ii) practice communicating your strengths and interests in a concise manner, and (iii) seek feedback for continued improvement.

3.4. You have landed your first industry job—congrats! What should you expect?

Starting your first industry job is a lot like becoming a first year grad student all over again. You are thrown into an organizational structure in which you have no prior experience and expected to become self-sufficient reasonably quickly. You'll often be working in a new technical area that you'll need to learn from internal technical reports, patents, and other resources instead of peer-reviewed scientific papers. Corporate jargon (especially product names) can take some time to pick up and become fluent in. In short, the learning curve when it comes to internal systems and processes should not be underestimated.

Unlike the academic setting, your future colleagues will be of very different ages, backgrounds, educational levels, and ambitions. Establishing good rapport with everyone in your workplace is essential to being successful. You will often need to call on people to help you with all sorts of things as you settle into an interdisciplinary team setting.

A common question we've both gotten from grad students is what does a typical day in industry look like? To answer this, we will again write independently of our own experiences in this section, as the day-in-day-out nature of one's work is different between large companies and startups.

Mike: "Scientists at Syensqo are expected to be independent stewards of their projects. On average I spend ~20% of my time in meetings with other team members, scientists on other teams we're collaborating with, or other project stakeholders to ensure mutual alignment. Of the remaining time, it's divided roughly half between physically doing work in the lab and data analysis/project management work at my desk. The amount of physical lab work done by PhD-level Scientists often depends on the number of direct reports they have. As a Scientist hires more direct reports, it is common for them to assume a role like that of a professor: you develop ideas, give guidance to your team's experimental work, analyze the results as they come in, and have dialogue with stakeholders to ensure alignment on project goals and timelines. Of course, I can only speak from my experience working at a heavily R&D-focused site. The type of tasks one works on can be very different if one is at a production site (for example, customer and plant support projects are more common)."

Jeff: "Scientists and engineers at 3M have vastly different day-to-day tasks depending on your entry position and role. My experience was in the corporate research lab in a core R&D role. I ran experiments in my hood and across shared instruments, but on average I spent about half of my time as a liaison for the MI Group to onboard projects to the digital platform. This involved setting up meetings, understanding technical details from projects, and cleaning data in spreadsheets (i.e., reformatting, correcting errors/gaps, compiling datasets). In working with materials scientists, I provided feedback to the data scientists and engineers on ways to improve the system with automated data ingestion and visualization. From this experience, one of the most important things I've learned is that you need to learn to manage your own time and bandwidth. Prioritization is everything—which translates well to working in a small startup.

In a large chemical or materials focused company, a scientist is immersed in a large hierarchy of experienced colleagues across diverse businesses. By comparison, a smaller company or startup offers more undefined roles, especially if it is a brand-new venture. At Nanite, I led initial efforts at building a well-equipped, functional lab in a shared incubator space. Initially, I was the only polymer scientist generating material and data for SME co-workers with backgrounds in molecular biology, automation, and data science. One special aspect of working in a small startup involves growing the company and establishing its culture. I provided direct input to hire new scientists and engineers, assisted with small business proposal writing, and created presentation materials for stakeholders. Nanite now comprises over a dozen individuals across the founding, experimental, and machine learning/AI teams. We have built an ever-growing platform that integrates computational design, rapid polymer synthesis, and biocharacterization. We leverage our capabilities to offer nonviral delivery solutions to patient advocacy groups, including the Cystic Fibrosis Foundation and the Bill & Melinda Gates Foundation, and advance gene therapies for a growing number of pharma and biotech partners. It is difficult to describe how proud I am of everything our small team has accomplished in this short amount of time!"

4. OUTLOOK FOR EARLY-CAREER INDUSTRIAL SCIENTISTS

For the purposes of this section, we will refer to early career industrial scientists as individuals within the first 5 years of entering the polymers workforce. While the scope of industrial polymers research is more diverse than ever and continues to evolve, there are common themes that are worth highlighting in terms of building a fulfilling career. We break this down by navigating the chemical industry based on company size, finding mentorship, and building community in a postgraduate world.

A highly popular subscription newsletter called The Polymerist[8] serves as an inspirational starting point for many of these takeaways, including topics that are not discussed at length here. We encourage industry newcomers to read over posts tagged Career Scientist. Five of our favorite recent articles we would recommend for career scientists are "The Fundamentals of

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Commercialization," "Moving On Up," "Modern R&D Is Tech Service," "On Burning Out," and "Intentionally Directing a Career Path."

4.1. Navigating the chemical industry

Like you might anticipate, there are advantages and drawbacks to working in a large company (500+ employees) versus a small company (<500 employees) that established career scientists can elaborate on. Larger organizations generally have more capital available, which spreads financial risk across teams that can span multiple businesses. These large companies can also be multinational, allowing opportunities to connect with international collaborators, travel to manufacturing and plant operations sites, and gain unique career growth opportunities. The customers and markets are more diversified, allowing opportunities to redirect your career path into highly specialized domains with many SMEs to learn from. However, this hierarchy may be accompanied by high level bureaucratic obstacles that need to be slowly navigated. At an individual level, you may have ownership of a project that has strong potential from a scientific standpoint, but decision-making on promoting it to the next level involves many stakeholders that must come to a consensus from a broader business perspective. The technology may not be ready to scale at the present point in time for commercial success.

In comparison, smaller organizations can be more agile, visionary, and mission driven. Here, the technology and underlying science typically aim to be disruptive in nature. Each decision is more influential in affecting the trajectory of the small company's growth. The phrase of wearing many hats (or in the T-shaped skills metaphor in Figure 2, becoming a bottlebrush-type person) at a smaller company is quite appropriate, as you may be asked to problem solve any number of blocks that come up. Additionally, if you are hired as an early employee in a small company, you may receive mentorship in entrepreneurship that many polymer scientists would not normally experience; an excellent account of polymer companies that have spun out of academic laboratories in 2021 describes this through many distinct examples.[9] One of the drawbacks to being in a smaller company as emphasized by the authors of this article, is that there is no direct path to success. The trade-off is the inherent risk of the company failing, which may be beyond the control of the team. Additionally, usually in early stages of a company, initial hires are only available for domestic applicants.

We also highlight the current landscape of opportunities available at startups in the data science and biotechnology space, which have greatly expanded opportunities for PhDs over the past 5 years. There is sustained movement now for industrial digitalization across chemical businesses. It was estimated that the global chemical industry aimed to spend over $4 billion on digital transformation technologies in 2023 alone.[10] Specifically, opportunities are now ample for SMEs with backgrounds in chemicals and materials to couple basic data science knowledge and advance industry's adoption of big data analytical tools, application/platform support, and unit operational modeling. In an editorial piece describing the recent rise of biotech companies,[11] Matt Krisiloff asserts that "If the company you're at doesn't work out, you can move easily because of the shortage of good scientists... It's the opposite of academia, where there are so many postdocs and so few professorships." Startups may not work out for a number of reasons, but there are many other biotech positions available for early career scientists.

4.2. Seeking mentorship and advocacy

We both have received the following advice from more experienced industrial scientists in our first months in industry: your direct manager should not be your only mentor! While it is important to be aligned with your manager on your career ambitions and progression over time, meet and talk with others at the company at all stages of their career, especially as a new employee. Learn about their unique paths, hurdles, setbacks, and pitfalls. Set up recurring meetings in the first few months as you equilibrate to the new workflow and project needs from your team. Nearly every experience is different, which may be why it is so difficult to find general advice on mentorship for industrial scientists. This mentality is very different from a student−PI relationship in grad school or during a postdoc.

There may be formal mentorship programs set up at your company, especially for brand new employees. While these may be valuable during the initial onboarding, spend some time to reach out to people at all stages of their career; do not just simply focus on the most senior person that has volunteered. In all likelihood, the highest ranked individual has been through organizational changes or market conditions that are valuable to understand the current company structure, but may not be directly transferable to your starting role today. Surface level advice on career development is just that. Instead, it is more advantageous to gain a broader range of perspectives that fulfill certain roles that advance small but meaningful opportunities in pursuit of your individualized career path.

To elaborate, we recognize that for early career scientists, advancing into senior leadership roles is often multifaceted and open-ended, especially compared to fulfilling outlined requirements for a PhD in academia. When navigating career pathways to advance up a technical ladder or transitioning up into a management position, achieving your technical goals and delivering value depends on the opportunities presented to you. This relies on a number of factors over time. We present the following thoughts about seeking support at your company, described by five broad roles based on select business articles that discuss the lack of female sponsorship that can potentially lead to diversifying top senior executive roles.[12]

- *Mentor* (**most private type of relationship**): provides general advice and support by investing time in regular meetings.
- *Strategic Partner*: shares strategic information about advancing your career in the company and offers you advice on developmental gaps.
- *Connector*: makes introductions to leadership and brings up your name to prominent people.
- *Opportunity Giver*: provides project opportunities with high visibility and impact to demonstrate impact and value for the company.
- *Advocate* (**most public type of relationship**): publicly supports career advancement, promotions, and award opportunities; privately champions your name and creates opportunities and recognition for you.

In this hierarchy, an individual can provide various degrees of support from *mentorship* to *advocacy*. A mentor offers their time to give private advice, support, and coaching as feedback to what you are experiencing. However, even the best mentor will yield limited opportunities for advancement if they are not able to publicly vouch for you in the decision-making process that advances your career. In comparison, a strong advocate can put their reputation publicly on your promotion into a senior role.

They act as a champion on your behalf and use accrued capital for you with other stakeholders. In between a mentor and an advocate, an individual can act as a strategic partner in career development, a connector to expand your professional network, or an opportunity giver that connects you to high visibility roles that are of value and impact to the organization. We recommend reflecting on identifying a broad array of more senior individuals that can fulfill aspects of these roles for advancing your career into leadership positions.

4.3. Building community

Building robust communities inside your company establishes a sense of belonging and purpose. These connections can allow meaningful conversations on experiences working in industry to take place, which enables career scientists to learn from each other at various stages of a career. Fostering a sense of routine and camaraderie depends on the culture set by leaders. From our observations when programs appear too top-down, enthusiasm for participation is usually hampered. In other words, although internal community building is valued by upper management to varying degrees for supporting long-term retention and productivity at an organization,[13] there need to be incentives for career scientists to engage. Is regular participation over time a part of the company's mission, values, and culture? Will community building opportunities allow newer employees to interact with midcareer scientists outside of the formal workplace setting? Is there appropriate recognition for volunteering time in these events from upper management? This is part of outlining the value proposition of organizing professional events, especially ones that demand more volunteer driven participation.

In conversations with many industrial scientists and engineers over the past few years, it has become clear that it has been challenging to maintain professional relationships outside of their respective companies. This is especially true for those of us that entered the workforce right before or during the COVID-19 pandemic. Career scientists inevitably cannot share as much as they can in academia. Interactions in a corporate setting are quite distinct from those maintained in research groups or through friends made at academic conferences. Some companies are more active at academic conferences, while others are more present at customer-facing trade shows. There are company reorganizations that may temporarily pause travel to in-person events. Unlike academia, there should be a clear value proposition for your attendance beyond just wanting to see interesting science—industry rates are becoming increasingly expensive, and travel uses project and collaboration time that would be otherwise spent with your team. If conference attendance is important, then building relationships with key academic or government collaborators (or especially customers!) who attend always helps your justification.

Outside of large gatherings, there are still numerous ways to be involved in professional organizations on a volunteer basis. We highlight two relatively new efforts from nonprofit U.S. scientific societies that support the polymers community through its volunteers. First, the American Physics Society Division of Polymer Physics (APS DPOLY) recently established an Early Career Researchers (ECR) in polymer physics community.[14] The APS DPOLY ECR hosts regular self-development educational seminars, disseminates employment opportunities in polymer science and soft matter, and organizes an annual virtual polymer physics symposium that facilitates technical talks and posters, career panels, and networking opportunities. In 2024, DPOLY also launched an industrial advisory board to strengthen industry interactions with 10 inaugural members across a range of business areas in polymers. APS at an organizational level also maintains an up-to-date physics jobs board for organizational recruiting. Second, the American Chemical Society Division of Polymer Chemistry (ACS POLY) has long supported an Industrial Advisory Board (IAB) to represent the voice of industry by enhancing and fostering industrial engagement through developing programming, education, recognition, and awards within ACS POLY.[15] Special effort is placed on providing industrial perspective on divisional programming topics at ACS national meetings, as well as rewarding outstanding industrial polymer scientists with recognition to the polymers community. Looking ahead, the POLY IAB aims to expand its member companies to small companies (<500 employees) and reflect growing representation in biotech startups and information technology companies that currently offer unique employment opportunities for PhD talent.[10]

5. OUTLOOK FOR ACADEMIC PROFESSIONALS

In this section, we speak to academics (mostly professors but also other professionals who are in student-facing positions) to help them understand how they can support their students' industrial job searches and eventual early careers. As fewer and fewer professors now have prior experience in the private sector, advisors may not always be aware of the specific differences between academic and industry job searches. Furthermore, many grad students have anxiety over the feeling that their advisors prefer them to go into an academic career.[6] The best way an advisor can help their students in this sense is to (1) offer even-handed advice on the difference between jobs in different sectors, and (2) be proactive in pointing their students in the right directions when it comes time for students to go on the job market.

5.1. Preparing your students for an industrial career

Just as companies desire to recruit the top talent coming out of grad school, so too does it reflect well on academic research groups to consistently place students in good jobs that lead to successful career paths. Considering that the overwhelming majority of PhD graduates in physical sciences and engineering will end up in an industry career (75%−79% according to the 2022 NSF Survey of Earned Doctorates[16]), setting students up for a successful job search is an integral part of building a robust pipeline. We offer the following advice to early career faculty whose students will soon be going on the industrial job market.

Above all, we must reemphasize that ***networking is everything***. As we mentioned in Section 3, a candidate can dramatically raise their chances of success by having an internal recommendation. A young professor is well-positioned to initiate these relationships for their senior students in several ways, including connecting the students with former grad school/postdoc colleagues who have gone on to industry, and encouraging the student to engage in industry recruiting events. Professors should also support opportunities that expose their students to industry professionals, like attending trade shows or conferences where an industrial presence is anticipated. One other venue for industry engagement that professors can influence is bringing industry professionals to campus. Virtually every academic department has a seminar series for which grad student attendance is mandatory; we challenge academics to invite industrial scientists to regular department seminars, which

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would in turn help foster industrial–academic relations among both faculty and students. For early career industrial scientists in certain companies, external opportunities may even be highly valued as metrics for internal promotion or career advancement. Finally, some companies offer internship opportunities for grad students. While these would require the student to spend a summer away from their university, a successful internship very often leads to a job offer and can furthermore help the student bring a more transversal perspective to their PhD research.

5.2. Integrating industrial scientists into the broader scientific enterprise

In Section 3, one of the drawbacks of an industry career that we outlined was the unfortunate reality that industrial scientists often become disconnected from their former academic networks. We believe the root cause of this phenomenon is the diminished participation of industrial scientists in the channels of open scientific dialogue, which is in turn linked to the different incentives for dissemination between academic and industrial sectors. In academia, most research findings are freely shared once they are written up into a manuscript, as this leads to a higher profile for the research group and better chances of subsequent findings. In contrast, the most impactful industry research is almost entirely kept within a "walled garden" in order to protect the company's IP. Results are often publicly shared once an IP position is secured or when a project is no longer a priority for the company. Even then, publicly shared industry research is usually sanitized to remove the most important technical details. This reality will certainly not change any time soon, so how then can the industry–academia divide be better bridged?

From our perspective, there are several actions that can be taken on both sides to foster better mutual engagement. On the industry side, companies can certainly be more proactive in inviting academic speakers to give internal seminars, whether on-site or virtual. Conferences are an excellent opportunity for local companies to do this, as academics will already be in the area which reduces the travel expenses for the company. Companies should also seek to participate in organizations that exist to help them interface with academia (the ACS POLY IAB[14] is an excellent example of this). Not only can these groups improve the company's visibility, which enhances long-term recruiting, but it can also be an opportunity for the company to influence technical programming at the parent body's conferences. Finally, we see room for more industry sponsorship of academic technical initiatives. We believe such actions cannot and should not be reduced to a raw value proposition—there is inherent value in being perceived as a good steward of the scientific enterprise.

On the academic side, we again echo the need to better incorporate industrial scientists in the existing technical networking enterprise. Remember, most graduate students will go on to industry careers, but many will also participate in at least one conference in their training. There should be collective intent at the level of national, regional, local, and even internal university conferences to seek out participants in relevant industries. We believe this effort should also extend to major technical awards. However, here we recognize a serious challenge in compatibilizing the industry and academic domains: how to effectively judge the merit of industry applicants, when industry research is necessarily opaque to outsiders? To be clear, we do not have a simple solution to this. However, we encourage academic organizations to consider ways to evaluate scientists' technical contributions that 1) include more than one's public publication record, and 2) do not require applicants to fully disclose their research projects/findings. Likewise, we encourage industry to be more proactive in encouraging their scientists to apply for top technical awards and to creatively contemplate how their applicants can safely share their technical expertise.

6. CONCLUDING REMARKS

Altogether, it is an exciting time to be an aspiring polymer scientist or polymer engineer! As of writing this Editorial in the beginning of 2024, the chemical industry as a whole appears promising.[17] Macromolecular materials continue to gain global importance, shaping the development of virtually every commodity product and specialty material in our everyday lives. From the first century of the field, we have developed a robust fundamental understanding of many different polymeric systems, but many grand challenges remain to be solved in not only the chemical industry, but also diverse industries that need innovative technologies. Early career polymer scientists and engineers now face diverse career choices and are confronted with more than a simple selection of "academia or industry?" after completing their PhD studies or postdoctoral training.

For students, the best advice is to be open to change and opportunities that may not be apparent at present. It is helpful to plan proactively and strategically in grad school–identify postdoc positions that give you complementary skills, apply to reputable institutions, or even move to a location with thriving ecosystems that support many positions that rely on your technical skills. We recognize though that depending on financial constraints or familial circumstances, some of these points are unattainable for many people. Although you are planning for the future, you do not know what your future self-wants or needs. You could encounter extraordinary people—mentors, friends, partners, collaborators—that can fundamentally change the trajectory of your life. These inflection points are almost always impossible to anticipate ahead of time. Your future self will be different than what you may expect it to be, so do not let the endless possibilities of what could have been (and what can be) overwhelm small steps that can be made every day. Play an active role in crafting the person you are going to become on a day-by-day basis.

For industrial colleagues, build your career proactively and deliberately. Today's economy and job market are incredibly different than they were a decade ago. We touched on this above, but like many unforeseen events in history, the effects of the 2020 pandemic are still unwinding for people and organizations alike. As an analogy for navigating ever changing career paths, we compare preparing yourself for unforeseen change akin to establishing ideal conditions for reversible deactivation radical polymerizations—where termination is always possible, but highly, highly unlikely. The vast majority of time, your role as a growing chain remains in an unreactive, dormant state. But when the opportunity arises, embrace controlled, continuous growth in size before quickly re-establishing an equilibrium state. Put in the work to keep learning new useful skills (technical, leadership, or project management) that can ultimately bring you to a role that keeps you energized and fulfilled.

For academic colleagues, understand that industry is still highly fertile ground for producing accomplished scientists. There is just as much prestige in producing a lineage of students who have gone on to high-level VP or technical fellow roles as there is in growing a large academic family tree. Also, understand

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Table 1. Concluding Summary of this Editorial

Section	Topic	Takeaway Points
Career Outlook for Grad Students/Postdocs	What creates success in industry?	- There is an abundance of opportunities for promotions or transitions to new technical or managerial positions after several years of strong performance. - You need to establish a track record of more independent innovation, often in the form of filed patents, new trade secrets, leading large capex projects, or contributing to a new product launch. - Developing strong project management skills is key—industrial teams are closely aligned on project goals and deliverables for project stakeholders.
	How do you get your foot in the door?	- The job application process is streamlined, but you need to stand out in screenings from hundreds of applications. - Having a referring contact at the company (other researchers, grad students and postdocs throughout your training) can greatly increase your odds of moving past the initial screening stage of an interview. - Remain patient and apply broadly. The first job is usually the hardest to get.
	Practical advice for interviewing	- Interviews typically have a combination of technical and behavioral questions—there can be more behavioral questions than you may expect that gauge how well you fit in dynamic team cultures. - Try to strike a balance in technical presentations between high level accessibility and mastery of the topic to subject matter experts. - We recommend thanking about questions can lead to conversations that simultaneously demonstrate your fit for the role and provide insight to the workplace culture.
	You have landed your first industry job—congrats! What should you expect?	- There is a learning curve to understanding the internal system processes and corporate jargon. - Experiences will vary depending on the company, but for R&D roles your time is divided into meetings, lab work, data analysis, and project management. - At smaller companies, you can have greater impact on hiring new scientists and engineers, writing business proposals, and building a physical lab space for your team.
Outlook for Early-Career Industrial Scientists	Navigating the chemical industry	- The current chemistry industry is broad: there are advantages and drawbacks to working in a large company versus a small company. - Larger organizations generally have more capital and diversified businesses, but decision-making involves greater consensus building from stakeholders and a broader business perspective. - Smaller organizations generally are more agile and mission driven but experience greater risk of the company failing from factors that may be out of the control of the team.
	Seeking mentorship and advocacy	- Meet with others at the company at all stages of their career, especially as a new employee. Learn about their unique paths, hurdles, setbacks, and pitfalls. - Try to gain a broader range of perspectives that can offer small but meaningful opportunities in pursuit of your individualized career path. - Seek out degrees of support from senior colleagues, ranging from mentors and strategic partners to opportunity givers and advocates. It is important to recognize different types of professional relationships you can build in an organization.
	Building community	- Building robust communities inside your company establishes a sense of fulfillment, belonging, and purpose. - Although it may be challenging to maintain professional relationships outside of a company, opportunities may arise with a strong value proposition for attending a large meeting or gathering. - There are also ways to be involved in professional organizations on a volunteer basis. The APS Division of Polymer Physics of the ACS Division of Polymer Chemistry offer direct opportunities for industrial engagement and representation.
Outlook for Academic Professionals	Preparing your students for an industrial career	- Networking is everything: faculty relationships with former trainees can be leveraged to alert students to employment opportunities. - We advocate for greater exposure to industry professionals through attending trade shows or conferences where industrial scientists are present; department seminars may also be an opportunity for fostering better industry-academia relationships. - Industrial internship opportunities for graduate students should be valued; these often lead to job offers and can offer a more transversal perspective to their PhD research.
	Integrating industrial scientists into the broader scientific enterprise	- Open scientific dialogue becomes limited in industry due to the need to protect intellectual property or trade secrets. - On the industry side, company leadership can be more proactive in inviting academic speakers to give internal on-site or virtual seminars, participate in organizations that interface with academia routinely, and sponsor technical initiatives. - On the academic side, we advocate for more collective intent of seeking out industrial participants at the national, regional, local, and internal university settings. This includes establishing awards or recognition of major technical accomplishments.

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that grad school is a half-decade-long marathon that can involve multiple changes in career ambitions—some students may begin with academic careers in mind before eventually realizing that industry is a better fit (and vice versa). The most important things an advisor can give a student toward the end of their PhD are objective career advice and patient support. We have been inspired in the past by some of our mentors who have "Alumni" pages on their group Web site that highlights the diversity of careers taken up by group graduates; we encourage all advisors to consider doing the same!

A concluding summary of this Editorial is provided in Table 1. Of course, there have been many articles and blog posts written about different aspects of finding a fulfilling industry career. To continue the conversation beyond our own personal journeys, we encourage further discussions at conferences and gatherings to include industrial polymer scientists, especially to represent more global viewpoints to discuss experiences not covered in this Editorial. While we do not have space in this Editorial to fully expound upon them all, we list four of them below with references for interested readers:

- *Glue work holds cross-disciplinary teams together and needs recognition*: Glue work was coined by Tanya Reilly for describing less prestigious and often nonpromotable tasks that benefit the organization,[18] especially as teams become more cross-disciplinary or multinational. Glue work describes volunteer-based tasks that do not contribute to performance evaluation and career advancement as a technical scientist or engineer. As a technical employee, caution should be taken for overcommitting to glue work at the cost of promotable work. Research has demonstrated the notable gender differences in women receiving and accepting more task allocations that are ultimately viewed with low-promotability when performances are evaluated, in both academic and in industry settings from field evidence.[19] Management should be cognizant of this tendency and evenly delegate glue work tasks that are considered important for successful teams.

- *"The industrial lab showed that the group—especially the interdisciplinary group—was better than the lone scientist or small team... [T]here were plenty of good ideas out there, almost too many. Mainly, they were looking for good problems"*:[20] This vignette describes a historical narrative around the founding principles of Bell Laboratories. Because business models of today (and academia, to some extent) no longer allocate near-infinite freedom or time to pursue any research interest without commercial application, we have witnessed the rise of independent, private research facilities with immense capital (e.g., $500M to $3B in the biotech space[21,22]) that directly compete with hiring talent against academic departments. To this end, senior academics have pointed out the loss of talent pool:[23] "After all, if a large number of very talented individuals leave academia for the private sector, who will train the next generation of scientists and provide discoveries to continue driving innovation at its most fundamental level?" We would like to raise a follow up question to this: where should young job-seekers look to have the most resources to be both (1) creative and innovative, and (2) financially compensated to live a fulfilling life outside of work? In our view, there are plenty of good problems that early career polymer scientists and engineers can address in industry that are purposeful but can perhaps better facilitate work/life interplay.

- "*When expertise is shared, extraordinary things are possible*":[24] This quotation from the 2018 NSF Frontiers in Polymer Science and Engineering report captures our perspective on the necessity of strong collaboration, both direct and indirect, between industrial and academic actors. Academic research still occupies a critical position in the broader scientific enterprise: it is often the birthplace of foundational knowledge that informs the development of innovative and life-enhancing products by industry. Yet, the coming need for materials with unprecedented performance will require the development of *new* concepts in polymer materials, not just incremental advances in existing technologies. A strong academy is absolutely necessary to meet these demands, coupled with a commitment from industry to rethink legacy materials and processes as well as an openness to collaboration.[25] However, the hypercompetitive landscape of modern academia and the accompanying (dis)incentives have made it almost impossible for early career faculty to perform radically unique research.[26] This is not just a matter of funding; increasingly, job postings for junior faculty are targeted at particular areas of research (e.g., sustainability) rather than openly seeking to recruit the most creative and talented candidates. In other words, prospective faculty are being explicitly encouraged to box themselves into trendy research topics in order to even get hired. It is critical that academia reorient itself again toward granting its professionals the freedom to pursue curiosity-driven research. After all, many of the most significant inventions on which modern society relies had their inception in esoteric findings that had unclear value propositions at the time.

- "*There will be no further explanation. There will just be reputation*":[27] In future faculty workshops that we have both attended in the past, the theme of "building your personal brand" has been emphasized to stand out in today's hyper-connected world. This can be somewhat difficult, as there is a delicate balance between substantive reputation building and empty self-promotion. General branding advice is available online as starting points,[28] but we believe professional scientists should realistically recognize the importance of networking and reputation building because of the unlikelihood of lifelong employment at a single organization. Over a decade ago in a 2011 Nature Chemistry commentary,[29] a senior director that oversaw strategic marketing and thermosets emphasized this: "Joining one company and staying for 35−40 years until retirement is becoming rarer... the odds that a company will be acquired, spun off, or combined with another enterprise in a joint venture are increasing. Developing, nurturing and protecting a personal brand is an important part of sustaining a successful career." In the end, it might be worthwhile to think about building your prospective career as building the anthology of works that reflect different periods of your life, balancing professional (and non-professional) needs and purposes as new opportunities appear.

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Notes

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