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BY THE NUMBERS: HOW ACADEMIC CAPITALISM SHAPES GRADUATE STUDENT EXPERIENCES OF WORK AND TRAINING IN MATERIAL SCIENCES

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BY THE NUMBERS: HOW ACADEMIC CAPITALISM SHAPES GRADUATE
STUDENT EXPERIENCES OF WORK AND TRAINING IN MATERIAL SCIENCES

A Dissertation Presented

by

TIMOTHY OSGOOD SACCO

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
Of the requirements for the degree of

DOCTOR OF PHILOSOPHY

February 2022

Sociology

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By The Numbers: How Academic Capitalism Shapes Graduate Student Experiences of
Work and Training in Material Sciences

A Dissertation

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ABSTRACT

BY THE NUMBERS: HOW ACADEMIC CAPITALISM SHAPES GRADUATE STUDENT EXPERIENCES OF WORK AND TRAINING IN MATERIAL SCIENCES

February 2022

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The neoliberal reorganization of higher education has reshaped the research and education missions of university science. Much of the scholarship examining this shift focuses on faculty experiences. This dissertation centers the experiences of student scientists to explore: (1) how entrepreneurial universities manage marginal academic knowledge workers, including students, through processes that shift responsibility onto individual workers; (2) how universities use mechanisms like internships and Individual Development Plans to shift educational responsibilities onto students; and (3) how performances of masculinity in commercial spaces of university science contribute to durable gender inequalities among students under academic capitalism. Longitudinal qualitative methods were employed to understand how students experience years of training in an academic capitalist context. The data for the dissertation were collected during a five-year ethnography in two academic science sites, and include 60 interviews with academic faculty, staff, and student scientists.

Findings show how universities shift responsibilities for handling job market instabilities or the devalued aspects of education onto academic staff, postdocs, and

students. Universities use accountability practices under the narrative that grad student scientists need to “take ownership” of their education. Universities create structures channeling undergraduate students into industry internships. Many material science graduate students also express a desire for industry experience, but faculty reliance on graduate student labor in academic labs deters students from holding internships.

Internship dynamics at both undergraduate and graduate levels reveal how students are commodified under academic capitalism. This dissertation also finds that men students are integrated into commercial spaces of academic science while women are excluded. These processes of gender inequality exclude women from innovation teams as well as from many resources available to commercially focused scientists.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS.....	iii
ABSTRACT.....	v
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
CHAPTER 1: INTRODUCTION.....	10
CHAPTER 2: SHIFTY INSTITUTIONS: HOW UNIVERSITIES BURDEN STAFF, POSTDOCS, AND STUDENTS.....	35
CHAPTER 3: TO BE OF VALUE: HOW STUDENT SCIENTISTS MAKE SENSE OF INTERNSHIPS.....	72
CHAPTER 4: INVENTING MASCULINITY: RELATIONAL PROCESSES OF GENDERED RESEARCH COMMERCIALIZATION.....	102
BIBLIOGRAPHY.....	135

LIST OF TABLES

	Page
TABLE 1.1.....	34
TABLE 1.2.....	34
TABLE 4.1.....	134
TABLE 4.2.....	134

LIST OF FIGURES

	Page
FIGURE 2.1.....	71

CHAPTER 1: INTRODUCTION

The rise of academic capitalism has had a profound effect on university science. In recent decades, the market has increasingly shaped academic science research agendas (Kleinman 2003; Berman 2012; Perkman et al 2012; Smith-Doerr 2016) as the boundaries between academic and industry science have blurred (Powell 1990; Kleinman and Vallas 2001; Smith-Doerr 2005). Scholars studying academic capitalism often focus on the growing tendency of faculty scientists to produce commercial outputs like patents (Geuna and Nesta 2006; Sampat 2006; NSF 2016) or startup firms (Bourzac et al. 2017; Brody 2017; Savage 2016). Others have focused on how university-industry relations (UIRs) support innovation among faculty scientists (Wapner 2016; Wright et al. 2014) and other processes of university technology transfer (Belitski et al. 2018; Bozeman et al. 2015; Etzkowitz et al 1998; Horner et al. 2019; Owen-Smith 2011; Powell and Grodal 2005).

However, academic capitalism has been more than just a growing normalization of commercial outputs in university science. Critical scholars have argued that academic capitalism is the byproduct of a broad neoliberal reorganization of higher education (Moore et al. 2011). I understand neoliberalism as a governing rationality that extends economic values, practices, and metrics to traditionally noneconomic spheres of life, “[which transforms] every human domain and endeavor according to a specific image of the economic” (Brown 2015: 10). Neoliberalism is more than policy; it is a style of governance that extends a market ethos. To understand academic capitalism, we need

research into organizational processes through which entrepreneurial universities govern the work of academic scientists, and the effects of these processes on education.

Over the last two decades, scholars have analyzed changes to university governance, exploring the “new standard of economic rationality... [that pervades] university decision-making” (Geiger 2004: 11; Kleinman and Vallas 2001). Universities are increasingly focused on processes of “counting and accounting” (Meyer and Bromley 2014; Krucken and Meier 2006). Tuchman’s (2009) ethnography of a public research university revealed how university administrators prioritize business values over educational values, and how this market ethos shape organizational decision making. As university administrators became increasingly focused on rankings, the university became more centralized, bureaucratized, and focused on commodification. Universities increasingly use audits to push faculty productivity (Douglas 1992; Powers 1997; Strathern 2000; Shore and Wright 2000). In an edited volume, Berman and Paradeise (2016) frame public research universities as organizations, “in which the balance of power between faculty and administrators has shifted... [as university leadership] identifies with business values...more than education values” (Berman and Paradise 2017: 9).

My dissertation is designed to address several gaps in the conversation on academic capitalism and the neoliberal reorganization of the university. First, I address an empirical gap around student experiences under academic capitalism. Scholarship on how academic capitalism shapes scientific work often centers the experiences of faculty scientists, investigating faculty research commercialization (Owen-Smith and Powell 2003; Leydesdorff, Etzkowitz, and Kushnir 2016) or faculty experiences with university

governance (Shore and Wright 2015). There has been less research into the experiences of students or other marginal university knowledge workers, like postdocs or academic staff. Berman and Paradeise write that, in their volume as well as the broader literature on changes to university governance, there is a “decided absence of students and their experiences... [this is] a major lacuna, particularly since scholarship can clearly take a student-focused approach while remaining quite organizational” (2016: 10). In setting an agenda for future research, they advocate for “organizational research that [begins] with students and emphasize the educational mission of universities” (ibid). My dissertation contributes to filling this empirical gap.

My dissertation also addresses several theoretical gaps in the scholarship. First, it speaks to how entrepreneurial universities manage marginal academic knowledge workers, including students. Research shows that universities use audits to shift responsibility onto faculty through accountability (Strathern 2000; Tuchman 2009). Universities tell faculty how and when they will be evaluated, and then recede into the background while faculty push themselves to meet their milestones. Audits have a disciplining effect in which workers come to manage themselves (Foucault 1975; Rose and Millar 1992). Scholarship on neoliberalism has shown that processes that shift responsibility onto individuals are common across institutional contexts (Brown 2015; Foucault 2010; Mounk 2017; Ong 2006; Shamir 2008). Within universities, we are left with a question of how administrators shift responsibility onto marginal knowledge workers, including students. What form does this responsibility shift take for marginal knowledge workers, and what are the implications for STEM education?

The second gap I address with this dissertation is how universities are responding to the changing job market faced by students. Students are facing an increasingly insecure job market following graduation, and a growing number of students are finding careers in industry (Sinche 2016; National Academies 2018). Universities have an education mission, to train students. They have programs designed to professionalize students to a certain profession. In recent years, it has become increasingly common for undergraduate students to gain “real world experience” through private sector internships (Perlin 2011). When and how do universities facilitate internships for undergraduate and graduate students? How do students understand these brief forays into industry in the context of their overall career trajectories?

Finally, my dissertation addresses a gap around how academic capitalism is tied to gender equity in academia (Ferree and Zippel 2015; Smith-Doerr and Croissant 2011; Whittington 2011). As public research universities have become increasingly businesslike (Slaughter and Rhoades 2004; Slaughter and Leslie 1996; Kleinman and Vallas 2001), they have weighed research commercialization more heavily in faculty promotion (McDevitt et al. 2014; Sanberg et al. 2014). Analyses of patents reveal that commercially active scientists are more often men (Colyvas et al. 2012; Ding et al. 2006; Hunt et al. 2013; Koning et al. 2020; Metcalfe and Slaughter 2008; Sugimoto et al. 2015; Whittington and Smith-Doerr 2008). Do neoliberal policies favor men? We need more research into how gender is related to experience in the academic capitalist system.

This dissertation is designed to fill these gaps. In the coming chapters, I address the following questions:

1. How do universities shift responsibility onto marginal academic knowledge workers? Is it similar or different to what the literature has found with faculty? What (if any) are the educational repercussions of the shift?
2. How are universities involved in students' decisions to work in internships? At what point in educational paths do student scientists take internships, and why? How do student scientists make sense of their internships in the broader context of their career trajectories?
3. As universities encourage faculty to commercialize research, how does gender shape who is included and excluded from commercial opportunities in academic science? What are the material repercussions of exclusion?

These questions deal with the experiences of marginal knowledge workers, processes of meaning making, and informal systems that reproduce gender inequality. To answer these questions requires qualitative research that allows understanding of context and observation of process. I conducted five years of ethnographic fieldwork in two academic science programs. The first is the Biomaterials Research Center (BRC)[1], an interdisciplinary research program that brings material scientists, engineers, and biologists together to use principles found in nature to solve market problems. The second program is the Soft Materials Research Traineeship (SMRT), a federally funded education program that trains STEM students how to communicate their research with interdisciplinary audiences from academia, industry, and government. I gathered the data necessary to answer my questions through on the ground observations and relationship

building. My fieldwork is supported by 60 in-depth interviews with academic faculty scientists, student scientists, and program managers.

In Chapter 2, I argue that universities shift market and education responsibilities onto marginal academic knowledge workers in tandem with pushing faculty to be increasingly entrepreneurial. Staff complete grant housekeeping, but their salaries are contingent on programs securing funding, meaning they feel funding insecurity in their personal lives. Postdocs manage the projects of a lab, but also take on much of the educational responsibility of the lab as well. Graduate students complete most of the benchwork to support the economic goals set by the university. Regarding education, both academic staff and postdocs are flexible positions, becoming a catch-all for devalued labor in the lab or in academic programs. This shift often includes educational responsibilities relating to mentorship or educational housekeeping. Universities are starting to use the audit document practices for faculty to shift educational responsibilities onto students. The marginality of staff, postdocs, and students, leaves all three in positions to take on devalued educational responsibilities while faculty are focused on research. Through my organizational approach, this chapter provides a better understanding of how universities embrace processes of responsibility shift as an institutional strategy to meet economic goals.

In Chapter 3, I find that it was extremely common for undergraduate students to work in internships, while graduate internships were relatively rare. Universities were involved in both undergraduates taking internships as well as graduate students not taking them. Universities push undergraduates to find internships as they are seen as valuable career preparation. Graduate students often desired industry internships, but the positions

came into conflict with the work expectations their supervising PIs had of them. Both the university dynamics around undergraduate internships and graduate internships reveal subtle processes of student commodification under academic capitalism. Students frame their internships as helping them become assets to future PIs or employers. Thus, this chapter reveals a tension between how students value their internship experiences and subtle processes of commodification.

In Chapter 4, I argue that masculinity facilitates how faculty and students experience the innovation contexts of academic capitalism. I find that gendered team and organizational processes around recruitment, division of labor, and visibility privilege men's continued integration in innovation contexts while simultaneously building barriers to women's integration. Once in these spaces, men learn a hegemonic physical science masculinity that centers market competition. Men learn to perform this "inventor masculinity" to navigate their inclusion in innovation contexts. These neoliberal organizational and interactional processes facilitate men's social closure around resources like funding, prestige, student labor, or space on campus. Thus, the growing valuation of research commercialization in academia creates opportunities for men faculty and students, and barriers for women faculty and student scientists.

DATA AND METHODS

My research is built on a five-year ethnography of BRC and SMRT. Here, I provide an overview of the public university context in which my two sites were embedded, as well

as background information on the sites themselves. I conclude this section by describing my approach to research methodology.

Public University Context

Both BRC and SMRT are located at the same university, a public research university in the northeastern United States. Like other public research institutions (Meyer and Rowan 1977; DiMaggio and Powell 1983), the university has become more entrepreneurial over time as administrators have prioritized economic values, practices, and metrics. Public research universities have become increasingly centralized, bureaucratized, and commodity focused as they center economic returns in their organizational policies (Tuchman 2009). Regarding education, public research universities increasingly treat education as a commodity to be sold (Clawson and Page 2011). Universities have unified branding missions on things like websites, school clothing, or sports uniforms. Universities are also increasingly focused on rankings. Universities compete with other institutions over national rankings that draw students (Arnone 2003).

The university celebrates research commercialization (Mowery et al. 2004; Powell and Grodal 2005), rewarding innovation in promotion decisions and featuring some faculty inventions in public relations materials like advertisements. The university established a university technology transfer office (TTO) in the mid-1990s as a strategy to engage the market through faculty entrepreneurship. As Colyvas and Powell (2006, 2007) highlight, technology transfer had become normative for universities by the 1990s.

The university I study was behaving similarly to other public research universities in its institutional field (DiMaggio and Powell 1983; Boh et al. 2015). TTOs help faculty scientists identify any novel inventions they may have produced and work with them to patent inventions. The TTO encourage faculty and student entrepreneurship by visiting classes, giving seminars. The TTO also works to facilitating UIRs; on their website, the TTO tells companies that “customer service is a key driver of any business, including ours.” They foster relationships with companies in hopes of negotiating licensing agreements, another source of profit for universities.

Like other public research universities, the university has used performance auditing (Strathern 1997; Powers 1997; Evans 2004). Administrators evaluate faculty on their publications and the funding they secure. Faculty at the university, particularly in the natural sciences and engineering, are rewarded for publishing or securing external funding in promotion decisions. Increasingly, the university has supported faculty entrepreneurship by rewarding patenting and startups during promotion.

My field sites

The Biomaterials Research Center is an interdisciplinary research program that brings together material scientists, engineers, and biologists to use principles found in nature to solve materials problems. BRC emerged from a collaboration between materials scientist Dr. Edward and Dr. Arnold, an evolutionary biologist. Together, their two labs developed a commercially successful bioinspired adhesive. After founding a startup to license their technology to interested companies, Dr. Edward and Dr. Arnold established

BRC to explore new research avenues opened by their commercial success. Today, BRC has 21 affiliated faculty collaborating on a range of projects. These faculty bring all the resources of their lab, such as instrumentation and student scientists, to BRC projects.

The Soft Materials Research Traineeship is an interdisciplinary education program funded through the National Science Foundation's (NSF) National Research Traineeship program. The co-PIs – Dr. Keyes and Dr. Lipton – had a goal to bring together life science, physical science, and engineering faculty to teach students in the interdisciplinary community of researchers using soft materials to address a variety of physical and life science problems. Specifically, the program is designed to help trainees communicate with scholars from other disciplines, policymakers, and industry stakeholders. The program is in many ways student-led; through a student leadership council, affiliated students determine what they see as important for their professionalization and communicate these needs to faculty. Through this student demand, the program has offered lab modules in skills like electro-spinning or fluorescent imaging techniques, and networking opportunities with companies visiting the university campus.

Methods

I ground my analysis in the daily experiences of academic knowledge workers. My years of fieldwork gave me a window into how the rise of academic capitalism shapes the experiences of university knowledge workers, and with what consequences for education. Becker (1996: 57) writes that one of the many epistemological advantages of qualitative

research is that it provides an on-the-ground view of those being studied, and more accurately portrays the research subjects' perspectives of their social worlds. My organizational approach allows for analysis of different workers' perspectives on academic capitalism, and how academic capitalism is unfolding in the research and education spaces of university science.

I observed the research center BRC from August 2014 until June 2019. Two years before I began my fieldwork, BRC PIs Dr. Edward, a materials scientist, had collaborated with Dr. Arnold, a biologist, on a commercially successful bioinspired adhesive. Bioinspiration draws on natural principles to address novel material problems (Finch 2017). When I met Dr. Edwards and Dr. Arnold, they were establishing BRC to pursue new research opportunities available to them because of their commercial success. A trusted contact introduced me to Dr. Edwards and Dr. Arnold. I began observing BRC early on, before the organization was funded and before there was a paid administrator on staff.

I observed the training program SMRT from August 2015 until December 2019. SMRT is a federally funded graduate traineeship program that teaches student scientists how to communicate their work with interdisciplinary audiences from academia, industry, and government. I worked on SMRT as a paid Research Assistant for five years. SMRT had written into their initial proposal funding for a "Science of Science" portion of the grant, studying how student scientists learned about collaboration and working with industry. This portion of the grant provided my funding for the grant period. I began observing SMRT early on, before any students had been admitted to the program.

There is a long history of ethnography in the sociology of science (Latour and Woolgar 1979; Traweek 1989 Knorr-Cetina 1999; Kleinman 2003; Vertesi 2020). Like many of these classic works, I spent some time observing scientists doing their work. However, I conducted most of my fieldwork during meetings. Formal meetings are important in organizational ethnographies because they are the spaces where those in power make decisions (Sanders and Thedvall 2017). Meetings provide space where rules, policies, and dynamics of knowledge production are structured, negotiated, or contested (Vertesi 2014). During my fieldwork, I observed faculty meetings, student meetings, classes, labs, seminars, and other formal meetings at each program. My field sites also allowed me to “scale down” organizationally; I observed the weekly lab meeting of two commercially focused labs affiliated with my field sites, each for a year. I travelled with respondents to conferences, attended backyard barbeques, and met students at the university pub.

Throughout my fieldwork, I reiterated my role as researcher to respondents in several ways. As Desmond (2012: 96) notes, “entrée is not something one does only once at the beginning of the fieldwork...ethnographers must maintain entrée day in and day out, and trust and friendship, under the unusual (and objectifying) context of research” (Also see Rainbow 1977: 29-30, Duneier 1999: 338). I explicitly reaffirmed my role as an observer by regularly reintroducing myself as an observer at meetings as new people came into the group. I affirmed my role as observer in subtle ways as well. For instance, in classes or lab meetings I would not sit at the conference tables with the rest of the faculty or students, instead choosing to sit along the perimeter of the room. At multiple

points during my fieldwork, faculty joked that I was like Jane Goodall, and they were like the chimps she studied.

In meeting contexts, I recorded fieldnotes openly rather than privately. I made this decision in the context of the formal setting of meetings in which note taking was normal for academic knowledge workers. Most people in classes or in meetings take notes, and so my notetaking was not out of the ordinary. Because I was often able to take notes openly, I would try to capture outlines of the meeting, including key topics covered, who interacted with whom, and snippets of dialogue. I would then revisit these outlines and fill in any blanks with as much detail as possible, usually within 24 hours of conducting fieldwork. There were times when openly taking notes was not possible, like at dinners, or hanging out with graduate students in their offices before or after class. In these instances, I relied on the traditional note taking in stairwells and bathroom stalls described by past ethnographers (Emerson et al. 1995; Duneier 1999).

In addition to my fieldwork, I collected 60 semi-structured interviews with academic faculty, students, and administrative staff affiliated with my field sites. These interviews allowed me to better understand respondents' histories and goals, as well as the forces that shape their lives. Table 1.1 categorizes my interview respondents by field site and structural position, while Table 1.2 categorizes my respondents by gender. I present these data in separate tables to protect the anonymity of my respondents. During interviews, I had two questions about how my respondent's gender helps or hinders their relationships, but overall gender was not the focus of my interview script. Often, interviewees described gendered experiences without prompting. These were often moments in which I would pause to explore the gendered aspects of what my respondent

was describing, and what repercussions followed. For instance, I asked all my students if they had negative experiences during their internships. Some women students brought up specifically sexist instances as negative experiences in their internships. In these moments, I would pause to discuss these instances in order to better understand how they navigated these experiences. I also collected additional program content related to my sites. I coded all these data—fieldnotes, interview transcripts, and written program materials-- using NVivo qualitative analysis software.

My positionality as a straight, white cis-gender male undoubtedly shaped my access and the types of data I was able to produce. I showed up on my first day of fieldwork wearing jeans, sneakers, and a plain button-up shirt. I was indistinguishable from the other three graduate students in attendance, all of whom were white men. My positionality certainly benefited me in some situations. I believe it gave me greater access in social situations in which there were no women present; I was privy to comments or stories from men respondents that I would not likely have seen had I had a different gender/race identity.

CONTRIBUTIONS TO ACADEMIC CAPITALISM THEORY

My research highlights how the entrepreneurial university shifts market and education responsibility onto precarious knowledge workers. After describing these processes, I discuss their impacts and how university science profits from the labor of precarious knowledge workers. Finally, I discuss my contributions to critical theory on systems of masculine privilege in commercial spaces of academic science.

Market Responsibility Shift

While neoliberalism unfolds differently across institutional contexts (Harvey 2005; Ferguson 2006), processes that shift responsibility to manage the instability and competitiveness of markets onto individuals are a common feature across its iterations. By responsibility, I refer to the institutional construction of individuals as accountable self-investors that are capable (and thus responsible) for shouldering market risk or burden (Mounk 2017). Neoliberalism employs an ethos of self-government (Ong 2006); assuming individuals as responsible decision makers capable of shouldering market risk (Shamir 2008; Sharone 2013). A central process of neoliberal governance is the deployment of this “human capacity for responsibility...to constitute and govern subjects, and through which their conduct is organized and measured” (Brown 2015: 28). Responsibility shift is a process of “[moralizing] economic action” (Shamir 2008: 1) through which individuals are made responsible for market risk or burden.

With the rise of academic capitalism, universities have shifted market responsibility onto faculty scientists using audits. While tenure and promotion have always been competitive, universities use audits to push faculty to be more productive than ever before. There has been a proliferation of audit cultures throughout society (Strathern 1997; Powers 1997; Evans 2004). Research universities evaluate faculty scientists on their ability to write high-impact publications, secure grants, and develop productive ties with industry (Slaughter and Rhoades 2004; Glausiusz 2019). Universities make clear the

metrics by which academic faculty will be evaluated for promotion through annual audits, which leads faculty to govern themselves.

Do universities shift market responsibility onto marginal academic knowledge workers, including students? I show that universities shift market responsibility onto academic staff, postdocs, and student scientists, though this process unfolds differently based on the structural location of the worker. For instance, academic staff are paid through secured research grants rather than supported by the regular university budget. Thus, academic staff face personal insecurity when the programs they run cannot secure adequate funding. Staff often spearhead efforts to find external funding, despite this proposal writing often beyond the scope of their job. Thus, like any market ventures, faculty startups or risky programs may fail. Universities encourage their faculty to take market risks, but do not support the staff when programs cannot secure funding. This process pushes market risk directly onto staff.

Postdocs experience market responsibility shift in a different way than either faculty or staff. A recent survey conducted by Nature highlights the market insecurity shift faced by postdocs. Postdocs face an insecure academic job market that is increasingly less likely to pay off while providing a growing pool of cheap, skilled labor to university science. The postdoc becomes responsible for their own academic success; universities benefit from their flexible labor while they search (Powell 2015; Woolston 2020a; Woolston 2020b; Woolston 2020c). In Chapter 2, I show postdocs often take on devalued tasks in the lab, a common characteristic of precarious positions (Millar 2017). Like postdocs, student scientists face a precarious job market. In Chapter 3, I show that universities sell opportunities like internships or other professional experiences to

students as opportunities that will boost their human capital, thus making them competitive in the job market. It becomes a student's responsibility to opt into these added experiences on top of their formal educational experiences to be competitive for future opportunities in a competitive market.

My dissertation shows that while all academic knowledge workers experience some sort of market responsibility shift, their experiences differ depending on their structural location in the academic research hierarchy. Through this analysis, my research provides a more nuanced picture of responsibility shift as organizational strategy employed in a systematic way to achieve desired economic outcomes.

Education Responsibility Shift

Interconnected with market responsibility shift, I argue that student scientists experience education responsibility shift. As I discussed above, faculty are rewarded for research productivity. Universities expect faculty to be self-investing entrepreneurs that pursue economically valued goals, like publishing in high impact journals, being highly cited, or securing prestigious grants. Universities reward faculty for commercial success as well. In this academic capitalist context, a market-based approach to undergraduate education has proliferated (Clawson and Page 2011), but there has been a devaluation of graduate education and mentorship (Slaughter and Rhoades 2004). I argue that universities employ strategies that shift the responsibility from academic faculty scientists to student scientists.

In Chapter 2, I show how universities employ audit strategies typically used to manage faculty to push students to take ownership of their education. Empirically, I analyze the rollout of an ‘Individual Development Plan’ (IDP), an annual check-in in which students rank themselves on their strengths and weaknesses as an independent researcher and outline necessary steps to achieve their career goals. The IDP is then shared with their PIs, who provide feedback on how the student evaluated themselves. IDPs occur annually, allowing faculty to be largely uninvolved in the mentorship of students. Instead, IDPs allow faculty to withdraw, “simply checking the resultant indicators of [student’s] performance” (Strathern 2000: 4). Students are responsible for working towards and becoming an “independent researcher” and taking ownership of how they achieve their careers. Through this process, universities reduce students “to the capacity for economic advantage” (Brown 2015: 23).

Similarly, in Chapter 3 I talk to some students who attended undergraduate institutions that have mandated industry internships to boost student’s competitiveness on the job market. Students understand their internships as opportunities to build their human capital (Becker 1964). In part, students have this understanding because that is how universities sell internships to students. Human capital theory has been central to neoliberal ideology (Foucault 2010; Brown 2015) and to the academic capitalist approach in higher education (Sawyer 1978; Walters 2004; Holden and Biddle 2016). Business scholars have championed ‘human capital’ as a key resource for both individuals and organizations in the contemporary economy (Barney 1991; Becker 1964; Coff and Krysyński 2011; Ployhart and Moliterno 2010). Human capital theory posits that individuals gain skills and experiences that set them apart from other applicants, while

organizations benefit because the human capital they acquire helps them produce a greater economic value (Bozeman et al. 2001; Coleman 1988; Peteraf and Barney 2003).

My dissertation demonstrates how universities shift responsibility for education onto students themselves to free up faculty efforts for research and to get students to be accountable for their career success. My research also offers up a critique of this human capital model that entrepreneurial universities use. In line with classic contingency theory (Cyert and March 1963; Thompson 1963; Scott 1981; Hinings and Tolbert 2008) I argue that universities emphasize the importance of human capital in STEM because the job market is increasingly uncertain. While the university has become more connected to the market over time, universities have been less able to provide students secure job prospects post-graduation. Thus, the emphasis on human capital and education responsibility shift makes students accountable for their career success while also freeing up faculty for more valued tasks.

Precarity

My dissertation also contributes to sociological theory on precarity. I understand precarity as a byproduct of neoliberal capitalism that manifests as instability, insecurity, or flexibility across institutional spheres (Butler 2006; Pugh 2015; Tsing 2015). In the workplace, precarity has emerged as a dominant labor condition across institutional contexts (Kalleberg 2018), with jobs becoming increasingly, “uncertain, unpredictable, and risky from the point of view of the worker” (Kalleberg 2009: 2). Careers once considered stable are increasingly risky or vulnerable to market instability (Bourdieu

1999; Han 2018; Millar 2017; Standing 2011). In this dissertation, I highlight how precarity is experienced by different participants in academic science and the implications for STEM education.

I contribute to this conversation empirically, showing the various ways that marginal academic knowledge workers experience insecurity. But I also contribute to theory regarding how precarity operates within organizations. A study of music industry interns shows that precarious jobs are often vague or amorphous, meaning different things to different workers in the structural hierarchy (Frenette 2013). Similarly, I find that the precarity of academic staff and postdocs is not just tied to pay or market insecurity. Like other precarious jobs, there is an ambiguity to staff and postdoc positions, which means they are easily made responsible for devalued tasks in academic programs or labs. As I demonstrate in Chapter 2, this ambiguity includes the “academic housekeeping” of education initiatives and the responsibility for mentorship. Just as universities employ tactics to shift educational responsibilities onto student scientists, they also take advantage of the open-ended nature of academic staff and postdoc positions to shift educational responsibilities away from faculty. Processes that shift educational responsibilities onto staff and postdocs then free up faculty to focus on economically valued outputs.

Privilege in Commercial Science

In Chapter 4, I investigate how academic capitalism has implications for gender equity in higher education (Ferree and Zippel 2015; Smith-Doerr and Croissant 2011;

Whittington 2011). Institutions of higher education have become increasingly businesslike, valuing knowledge privatization and for-profit strategies “that favor institutions, inventor faculty, and corporations” (Slaughter and Rhoades 2004: 29; Slaughter and Leslie 1996; Kleinman and Osley-Thomas 2014; Kleinman and Vallas 2001). In recent years, universities have promoted profits by weighing research commercialization more heavily in faculty tenure and promotion decisions (McDevitt et al. 2014; Sanberg et al. 2014). ‘Research commercialization’ refers to the conversion of knowledge produced at universities into market products, specifically patents (Maktabi 2009). Bibliometric analyses of patents find that commercially active scientists are more likely to be men (Colyvas et al. 2012; Ding et al. 2006; Hunt et al. 2013; Koning et al. 2020; Metcalfe and Slaughter 2008; Sugimoto et al. 2015; Whittington and Smith-Doerr 2008). Thus, weighing research commercialization more heavily in tenure and promotion favors men.

In academic science, the growing valuation of research commercialization creates unique opportunities for men scientists to find security in a field of growing instability. I find that gendered team and organizational processes around recruitment, division of labor, and visibility privileged men’s integration into innovation contexts while simultaneously excluding women. This mentoring advantage gives men students unique access to commercial skills that, in theory, make them more competitive on the job market. Thus, the growing valuation of research commercialization creates unique opportunities for men scientists to find security in a field of growing instability. The university prioritization of research commercialization has created another context for a gendered ‘Matthew Effect’ to flourish in academic science, in which male privilege

begets more privilege (Smith-Doerr 2011; Zuckerman 2011; Rossiter 1993). My research demonstrates how faculty recruit male students into innovation networks, and the ways faculty in those networks benefit.

CONCLUSION

My dissertation contributes to theory on academic capitalism by showing how entrepreneurial universities manage marginal academic knowledge workers, including students, or respond to the changing job market needs of students. It also shows how academic capitalism is tied to gender equity in academia. My findings open the door for future avenues of scholarship. For instance, more research is needed into how universities shift market and educational responsibilities onto marginal knowledge workers. A future study could more closely investigate the experiences of postdocs and academic staff, investigating specifically how they navigate precarity. More research is also needed into how education is being devalued under academic capitalism.

As universities develop ties to the market, they have adopted traditionally industrial practices (Kleinman and Vallas 2001). Below – in Chapters 1 and 2 – I investigate empirical cases of Individual Development Plans and undergraduate internships. Both are industry practices that universities have adopted in recent years to manage students. More research is needed into other industrial practices that have been adopted by universities to manage student scientists, and how these practices may shape the power dynamics between students and faculty. In Chapter 3 I show the dynamics around internships lead to the commodification of students; Slaughter and Leslie (1996) predicted that students

would be increasingly commodified under academic capitalism, but empirical research into this point is scarce. More research is needed both into what industry practices are being adopted in STEM educational contexts, but what the effects of these practices are on the autonomy and well-being of students.

More research is also needed into how academic capitalism facilitates social inequality. In Chapter 4 I show that dynamics around gender, particularly masculinity, facilitate men's integration into innovation contexts while simultaneously creating barriers for women. This line of scholarship would benefit from a more intersectional approach. Critical scholarship has shown how organizations enact seemingly neutral policies that reinforce gender (Acker 1990; Mickey 2019; Smith-Doerr et al. 2019) and racial inequality (Wooten and Couloute 2017; Ray 2019). A more intersectional approach to understanding how the neoliberal reorganization of higher education unevenly affects workers by race or gender. One particularly fruitful area of study would be how academic capitalism shapes the experiences of domestic and international students differently. More research is also needed into how race and gender facilitate integration into innovation networks.

[1] I have promised confidentiality to all my respondents. Therefore, I have provided all individuals and organizations with pseudonyms, and redacted any identifying information.

CHAPTER 1 TABLES

Table 1.1: interviews in two sites by position

	Biomaterials Research Center (BRC)	Soft Materials Research Center (SMRT)
Faculty	9	7
Graduate students	1	38
Undergraduate Students	3	0
Administrative Staff	1	1
Total	14	46
		Total Interviews: 60

Table 1.2: interviews by gender and position

	Women	Men
Faculty	4	12
Graduate students	16	23
Undergraduate Students	1	2
Administrative Staff	2	0
Total	23	37
		Total Interviews: 60

CHAPTER 2: SHIFTY INSTITUTIONS: HOW UNIVERSITIES BURDEN STAFF, POSTDOCS, AND STUDENTS

Global economic shifts over recent decades gave rise to academic capitalism, “market and market-like behaviors on part of the university and faculty” (Slaughter and Leslie 1996: 11). Universities have become increasingly businesslike, centering economic values, practices, and metrics. For instance, Kleinman et al. (2011) show how discourse at universities have increasingly prioritized greater emphasis on investment returns over time. Academic capitalism has had profound implications for the careers of faculty scientists (Hackett 1990). Increasingly, faculty commercialize their research (Owen-Smith and Powell 2003; Geuna and Nesta 2006; Sampat 2006; NSF 2016), found startups (Bourzac et al. 2017; Brody 2017; Savage 2016) and collaborate with industry (Smith-Doerr and Croissant 2011; Perkmann et al. 2013). The growth of academic capitalism caused universities to prioritize economic metrics over educational values. For instance, universities have increasingly used evaluation practices that encourage faculty to produce more and at higher rates, secure external funding, and tailor their work to the market (Espeland and Saunders 2016; Shore and Wright 2000).

There has been substantial research analyzing how academic capitalism has shaped the careers of academic faculty (Owen-Smith and Powell 2003; Leydesdorff, Etzkowitz, and Kushnir 2016; Slaughter and Rhoades 2004). For instance, public research universities have increasingly used audits to drive faculty productivity (Meyers and Bromley 2014; Strathern 2000; Tuchman 2009). After outlining how and when faculty will be evaluated, universities recede into the background while, ideally, faculty push themselves to meet these milestones (Shore and Wright 2000). The use of audits has

a disciplining effect (Foucault 1975; Rose and Millar 1992), making it a faculty member's responsibility to govern themselves to meet milestones (Brown 2015; Foucault 2010; Mounk 2017; Ong 2006; Shamir 2008). As universities become more entrepreneurial, they have embraced organizational strategies that push responsibility onto faculty to boost research productivity. Do universities use similar responsibility shift processes to manage more marginal academic knowledge workers?

To address this question, this chapter analyzes how universities shift responsibility onto academic staff, postdocs, and student scientists. I draw on theories of precarious work (Bourdieu 1999; Castells 2003; Kalleberg 2018) and audit cultures (Powers 1997; Strathern 2000; Shore and Wright 2000; Shore and Wright 2015) to analyze my data. Theories of precarity and audit cultures explain different processes of neoliberal governance that university administration uses to shift responsibilities onto workers. It would be impossible to understand the full extent of how universities shift responsibility onto different knowledge workers without drawing on both theories. By focusing on how responsibility shift occurs for workers situated at different places in the university hierarchy, I contribute to the theory of responsibility shift as a systematic organizational strategy for cutting costs and meeting metrics.

The labor of academic staff is integral to the success of science, technology, engineering, and mathematics (STEM) research and education programs, but academic staff pay is tied to externally secured funding rather than being supported by the university. Thus, while a faculty scientist may be negatively evaluated by administrators if they do not secure funding, they do not experience financial insecurity in ways that staff do because of funding shortages. Similarly, there are growing pools of postdocs

while postdoc positions are increasingly less likely to lead to a permanent job. This precarity has created a growing pool of contingent labor which universities conveniently exploit (National Academies of Science 2014; Woolston 2020a; Woolston 2020b). Like postdocs, graduate students face an increasingly insecure job market. While many student scientists are pursuing industry careers, universities have been slow to make structural changes in how students are trained (National Academies 2018; Sinche 2016; NSF 2013). Instead of adjusting to the changing needs of students, they find creative ways to shift educational responsibility onto students.

Under academic capitalism, universities drive faculty scientists to focus on research and other economically valued metrics, often to the detriment of STEM education. In my research at the Biomaterials Research Center (BRC), I find that academic faculty remain focused on research and grant writing, while much of the educational initiatives of academic science programs are shifted to program managers. Similarly, in academic labs, PIs focus on research and grant writing while postdocs shoulder much of the educational responsibilities of the labs. Universities are increasingly using audits to get student scientists to take ownership of their PhDs. Faculty remain focused on economically valued outputs while marginal academic knowledge workers take up the devalued responsibility of education.

NEOLIBERAL GOVERNANCE IN ACADEMIC SCIENCE

I build on critical scholarship that understands academic capitalism as the neoliberal reorganization of higher education (Moore et al. 2011). Scholars have shown

that neoliberalism unfolds differently across various institutional contexts (Harvey 2005; Ferguson 2006). However, one unifying characteristic across its iterations are processes that shift responsibility onto individuals to manage the instability and competitiveness of markets (Shamir 2008). Neoliberalism employs an ethos of self-government (Ong 2006); assuming individuals are responsible decision makers capable of shouldering market risk (Shamir 2008; Sharone 2013). By responsibility, I refer to the institutional construction of individuals as accountable self-investors who are capable of shouldering market risk or burden (Mounk 2017). Under the neoliberal reorganization of society, administrators exploit this “human capacity for responsibility...to constitute and govern subjects” by organizing and measuring their conduct. To be “responsible is to have capacities for adaptation or accountability” (Brown 2015: 133).

With the diffusion of academic capitalism throughout higher education, entrepreneurial universities have embraced industry processes that shift market responsibility onto academic knowledge workers. I argue that universities also shift educational responsibilities away from faculty and onto marginal knowledge workers. As universities have embraced academic capitalism, several aspects of education have been devalued vis-a-vis research (Slaughter and Rhoades 2004). Undergraduate education has been increasingly commodified (Tuchman 2009; Clawson and Page 2011) but graduate education and other educational initiatives are not rewarded as much as research in the neoliberal university. I saw this value system in my research as well. For instance, during a seminar in which faculty scientists talked to students about the tenure process, one faculty scientist warned students not to get too involved with teaching. “The faculty that get teaching awards are the ones that don’t get tenure. It’s sort of a kiss of death,” he says

with a smile, getting some laughs from the room. I argue that as universities push faculty to be more productive researchers, they employ processes that shift education responsibilities onto staff, postdocs, and students. Through this educational shift onto marginal knowledge workers, universities keep faculty narrowly focused on the research outputs by which campuses are ranked.

UNDERSTANDING RESPONSIBILITY SHIFT: PRECARITY AND AUDIT CULTURES

This chapter draws on theories of precarity (Butler 2006; Kalleberg 2018; Lorey 2015; Millar 2017; Pugh 2015) and audit cultures (Douglas 1992; Strathern 1997; Strathern 2000; Powers 1994; Powers 1997; Shore and Wright 2015) to understand how entrepreneurial universities shift responsibility onto academic knowledge workers. Theories of precarity explain growing workplace flexibility, insecurity, or risk, while theories of audit cultures explain the growing use of metrics to govern how workers practice and perform accountability. Together, these theories provide a framework to critically analyze how entrepreneurial universities shift market and educational responsibilities onto marginal academic knowledge workers. I use these theories to show how responsibility shift processes have unintended consequences for STEM education.

Precarity in Academic Science

Precarity is a byproduct of neoliberal capitalism that manifests as instability, insecurity, or flexibility across different contexts (Butler 2006; Pugh 2015; Tsing 2015). Sociologists studying precarity often focus on how work has become less secure over time (Bourdieu 1998; Castells 2003; Kalleberg 2009; Vosko 2010; Millar 2017). Precarity has emerged as a dominant labor condition in contemporary society, with jobs becoming increasingly, “uncertain, unpredictable, and risky from the point of view of the worker” (Kalleberg 2009: 2). Across the globe, the neoliberal reorganization of states and workplaces has caused a steady erosion of worker protections (Bourdieu 1999; Castells 2003; Kalleberg 2011; Ross 2009; Vosko 2010; Sennett 1999; Frenette 2015). Precarity was once primarily associated with working-class jobs, but today it is felt by workers across the economic spectrum as work has become more transient, uncertain, or competitive (Han 2018; Millar 2017; Standing 2011). Careers once considered stable are increasingly vulnerable to market instability. This is true of academic science. Growing precarity is especially concerning because work insecurity has detrimental effects on worker’s health and social lives outside the workplace (Pugh 2015).

Entrepreneurial universities have increasingly used contingent or nonstandard work arrangements traditionally found in industry to manage economic uncertainty. For instance, universities have increasingly used flexible labor like adjunct faculty, contract workers, or part-time workers over time (American Association of University Professors 2017; American Federation of Teachers 2020; Clawson and Page 2011; Danaei 2019). Under academic capitalism, flexible labor “[supply] the fiscal and organizational flexibility that [university] administrators...demand” (Kleinman and Vallas 2001: 468).

In this chapter, I analyze how staff, postdocs, and graduate students experience precarity in academic science. Staff, postdocs, and students are all marginal in relation to academic faculty, but each are central to the academic knowledge production process. I argue that precarity unfolds differently for each work category. Through my organizational approach, this chapter provides a better understanding of how universities use precarity at a systemic level as a strategy to meet economic goals.

In a study of lab technicians, Barley and Bechky (1994) argued technicians were both central to the research process while also missing from social studies of science. They argued that scholars overlook technicians because of their marginal status vis-à-vis faculty scientists. I would argue that academic staff are just as important to university science but are even more marginal than research technicians. There has been very little research on the experiences of academic staff. We do know that, as science has become more interdisciplinary (Frickel et al. 2016), research and education are becoming formalized into large projects, centers, institutes, traineeships, and other programs. With more formal programs comes more formal requirements. For instance, a 2014 NSF report highlighted the growing administrative and compliance requirements of federal funding over time. Academic staff are responsible for much of this added work, doing the housekeeping of scientific grants and programs (Hatton 2017; Shelton and John 1996). Academic staff are gender-typed feminine positions that are responsible for much of the devalued work of academic science (Acker 1990; Martin 2003; Martin 2013; Smith-Doerr et al. 2019). This paper speaks to a gap around how precarity is experienced unequally by different identities (Misra 2021).

There is more research on the precarity of postdocs (Lee et al. 2013; Kahn and Ginther 2017; Sauermann and Roach 2016). Today, it is common for new PhDs pursuing academic careers to work a postdoc before securing a tenure track job. In recent decades, the number of science and engineering PhDs granted in the U.S. has dramatically increased. In 2000, U.S. universities awarded 26.1 thousand science and engineering PhDs; in 2006, that number had risen to 30.3 thousand; in 2016, it had risen to 39.7 (NSF 2020). On the other hand, there are not enough academic jobs to keep up with the growing demand. Academic faculty are retiring at slower rates than in previous generations, and universities focused on the bottom line have systematically cut support for tenure lines across higher education. These conditions have created a backlog of postdocs. A recent *Nature* survey of over seven thousand postdocs found that 48% had been in their position for more than three years. 30% had worked two or more postdocs without finding permanent employment. One third of postdocs described their position as worse than they expected. 56% reported a negative view of their career outlook, and fewer than half said they would recommend their careers to their younger self (Woolston 2020).

I argue that both academic staff and postdocs are subject to processes that shift market responsibility onto them, but this looks different for each. For academic staff, pay is tied to research funding; in instances when faculty are unable to secure funding for programs, academic staff are some of the first expenses cut. Similarly, universities employ postdocs as skilled workers moving projects forward despite growing insecurity in the academic labor market, leaving postdoctoral fellows responsible for navigating the market. Both academic staff and postdoc positions are ambiguous, meaning they often

become a catch all for devalued labor, including educational responsibility. Below, I highlight that in academic science programs and labs, educational responsibilities are shifted from academic faculty to marginal academic knowledge workers. Postdocs are recognized as important lab mentors (McConnell et al. 2018), but to my knowledge there are no other studies looking at the link between precarity in science and who takes on educational responsibilities in academic science. My work fills that gap.

Finally, I focus on the precarity of student scientists. Like postdocs, graduate students are important to academic knowledge production, while also facing an increasingly insecure job market. As a result, many students choose to pursue industry careers (Amsen 2011; Austin 2013; Sauermann and Roach 2012; Turk-Bikakczi et al. 2014). Universities have been slow to respond to students changing labor market strategies. Instead, universities find novel ways to shift responsibility onto students (Sinche 2016). I argue that, like postdocs, graduate students are put in a position to shoulder market responsibility while universities benefit from their labor. And like staff and postdocs, students are also subject to educational responsibility shift. To fully understand this process, I draw on theories of audit cultures.

Audit Cultures

Scholars of audit cultures investigate the neoliberal reimagining of accountability in the workplace driven by, “an instrumental, results- and target-driven normative order that governs by numbers and, more importantly, through numbers” (Shore and Wright 2015: 430; Rose and Millar 1992). Driven by metrics, workplace administrators use

audits to regulate employees' economic efficiency and practice through formalized checkups. Management makes clear the practices or measures whereby academic faculty will be evaluated, workers manage themselves (Shore and Wright 2000). Management can then "withdraw to the position of simply checking the resultant indicators of performance" (Strathern 2000: 4). Through audits, workers become "self-managing individuals who render themselves auditable" (Shore and Wright 2000: 57). Processes of accountability have become the norm in higher education (Stevens and Kirst 2015), including audits. Shore and Wright (2000: 79) describe university use of audits as "coercive accountability... [that encourages] a form of 'reflexivity,' but the reflexive subject is caught within tightly fixed parameters that appear to render opposition futile." Data show that academic faculty are increasingly overworked, alongside a rise of benchmarks set by university administrators (Hobbins et al. 2012). Universities embrace audit cultures (Tuchman 2009; Shore and Wright 2015).

How do universities use audits to manage marginal knowledge workers like students? Below, I use the empirical example of an Individual Development Plan (IDP) to show how universities shift market and education responsibility onto students (Tsai et al. 2018; Vandeford et al. 2018). IDPs are career development tools that push workers to take ownership of their career development through a series of annual audits with advisors. Over the past decade, IDPs have become increasingly common in STEM. MyIDP (<http://myidp.sciencecareers.org/>), a popular web-based career planning tool for graduate students and postdocs, was launched in 2012. And IDPs are increasingly mandated by federal agencies making investments in STEM education (NIH 2014).

METHODOLOGICAL NOTE

In this chapter, I analyze how organizational changes driven by academic capitalism shape how academic staff, postdocs, and student scientists experience precarity, and what (if any) are the educational repercussions. Staff make up a small number of my overall respondents; out of 60 interviewees, only two were academic staff. Still, I observed BRC, SMRT, and the surrounding institutional environment for five years, during which I was able to observe the work experiences of academic staff, as well as how staff interacted with other academic science knowledge workers. The staff whom I interviewed were two of the respondents whom I got to know the best during my fieldwork. Reflecting their organizational status, I had more access to staff than the PIs. In my graduate Fieldwork & Interviewing class, we were always told to be the first to show up to the field site, and the last to leave. When I would show up to a meeting, it would be the administrative staff there early setting up chairs, making sure the food arrived and was paid for, that the projector worked. And so, it was the administrative staff with whom I had small opportunities to have a personal connection. They had valuable institutional knowledge of the programs I studied, and my relationships with them allowed me to collect rich data I would not have otherwise been able to access.

Next, I focus on the experiences of postdocs. Like staff, I had ample opportunity to observe postdocs during my five years of fieldwork. In one of the labs I observed, there were three postdocs leading different projects. And near the end of my observations at BRC, it became more common for postdocs to present at lab meetings. That said, I did not interview any of the postdocs I observed, in part because none were directly tied to the parts of labs or programs on which I was initially focusing. What I do have in my data

is faculty and graduate students discussing their relationships with postdocs, and how postdocs fit into the hierarchy of the lab. To understand postdoc positions, I pair my data with recent reports detailing the experiences of over seven thousand postdocs (Woolston 2020). Although it is an imperfect way to understand postdoc experiences, these initial findings have sparked many questions and I intend to focus more directly on postdoc experiences in future research.

Throughout my fieldwork, student scientists were the knowledge workers with whom I had the most engagement. I sat in on student meetings, late nights, walking the halls of the university trying to find a lecture in such and such a room, etc. Also, most of my interviewees are students (42 out of 60—see Table 1.1 – page 34). In this chapter, I focus on how student scientists face a responsibility shift through the rollout of an IDP program at their university. I observed faculty and student meetings in which the IDP was a primary point of conversation. I attended multiple university-led seminars on why and how to develop an IDP. And I asked students directly about their experiences with the IDP during interviews.

BEARING THE COSTS OF PRECARIETY IN ACADEMIC SCIENCE

I have organized my findings around different groups of marginalized workers in universities: academic staff, postdocs, and graduate students. I analyze how each position experiences precarity and undergoes a responsibility shift. I emphasize both the job market and educational responsibility shifts on these workers. I then highlight how these structural conditions have material implications for these academic knowledge workers.

Effects of Precarity on Academic Staff

During a seminar on grant funding, two faculty scientists are discussing the importance of staff for the success of large programs. One faculty member says, “We bring on staff because we need them. With these big grants, we can pay for staff...The problem is keeping staff funded.” Despite the importance of staff labor to academic knowledge production, they are not financially supported by the university for managing many scientific projects. Rather, research program staff are often supported through funded proposals.[1] This funding model was the case at BRC, where faculty often sought new ways to spin their research in order to support the salary of Colleen, their program manager. “Without grants or companies, [the PIs] can't research anyway,” Colleen says, “So they read through [funding calls], think, ‘Could I take my research in that direction?’ It's happening...to fill this grant need so I can keep my job.” BRC PI Dr. Edwards says “[a program manager] is critical for keeping faculty and students together. It's something that [is not supported by our university] ... so every year, more than once a year, we come together to check the budget and make sure that we have the right kind of funding [for Colleen]. That's been a challenge...”

Even when faculty secure adequate funding to support staff, staff positions are still incredibly unstable. For one, securing enough money to support staff over time is difficult, both because funding is increasingly competitive and because the funding priorities are always shifting. But how staff are paid within the university is also

precarious. For instance, Colleen explains that her pay through BRC had been inconsistent despite the center having secured a few large grants:

“When the grant comes in, it comes into the university. Unless the money is written in specifically to go back to BRC, we don't have any promise from the university to actually pay me. The money comes for me to work on the grant [because faculty set aside funds for me] but then nobody's paid to look for the next [funding] opportunity... Under BRC, it was our goal to help facilitate [industry] relationships and look for money. And we were doing that. But the money came in, and it goes to the department head, but they all hold the money, right? The 60% overhead [of the grant] or whatever it is [goes to the university]”

The institutional structures around how BRC secured grants and was allocated funds by the university created situations in which BRC did not have enough funds in their account to pay Colleen even if they had secured the adequate funding. The pay structure of staff also constrains their labor. As Colleen describes, nobody is paid to look for the next funding opportunity, despite the importance of funding both for research success and for the job security of staff. Faculty are often focused on meeting funding goals and writing proposals for funding opportunities. At BRC, much of the work of identifying potential opportunities fell to Colleen, despite it being beyond what she was paid to do.

I argue there is a job market responsibility shift that occurs through the structure of how staff are paid. We know that entrepreneurial universities have increasingly promoted faculty entrepreneurship (Slaughter and Rhoades 2004), which are often organized into research centers, institutes, and other large, bureaucratic programs

(Berman 2012; Bozeman and Youtie 2015). As faculty engage the market in increasingly entrepreneurial ways, some faculty ventures are going to fail. Most faculty scientists at BRC's university are on the tenure track, meaning they receive a 9-month salary which provides them with basic job stability when their programs don't secure funding.

In contrast, when research programs are unable to secure funding, the staff shoulder this burden in their personal lives. During one period in which BRC had only a few thousand dollars in their account, Colleen opted for a pay cut to stretch from one funding opportunity to the next:

“I'm in charge of the budget. I [realized] I had to drop to \$18.75 an hour [to stretch the funding]. Even with that, we would be out of money in December. We've had to basically come up with more money, or I would be unbenefited. I would be laid off and lose my benefits. If we cut my hours less than \$18.75, I lose all benefits, my family's insurance...

“So instead of crossing my fingers, I [found] other things...I'm now [working] \$15 an hour [at an educational program on campus] and \$10 an hour with [a larger collaborative grant]. In July, I'll start working as another project coordinator, so I'll be working for three grants. I'm not currently being paid by BRC at all.”

Colleen often commented on feeling interpersonally supported by the BRC PIs. They had friendships, and the PIs often treated Colleen as a collaborator (albeit without publication credit) on the projects they developed. The funding pressures they face and market insecurity trickles down to her personal life in ways faculty did not experience. Staff

members face a huge burden to stretch the budget on their own backs when times are tough, a trend observed in other sociological studies of scientific work as well (Reinecke 2021). Colleen reports taking a pay cut from BRC and lining up multiple gigs to maintain security for her family rather than taking pay that they had initially secured for her.

Staff positions are relatively ambiguous in tasks expected. Staff members are responsible for project housekeeping, which means the positions often become a catchall for several devalued tasks. In this context, I found that staff become responsible for educational activities of the program while faculty scientists focus on research. I saw this play out in both BRC and SMRT. For instance, BRC pursued education goals early in its existence through an undergraduate internship program. In faculty meetings, the PIs expressed excitement over the internship program, to engage promising undergraduates from the labs of BRC faculty. Interns also provided a source of cheap labor. BRC recruited six interns total (five men and one woman, see Chapter 4). Interns met weekly with BRC PIs Dr. Edwards and Dr. Arnold, and Colleen. Together in the lab they conducted market research, searched patent databases, interviewed people who used technology like what they sought to develop, and reverse engineered the products of their competitors.

After BRC received its initial funding, Dr. Edwards and Dr. Arnold began to focus their attention more heavily on research. It was increasingly difficult to get Dr. Edwards and Dr. Arnold in a room together because of how busy they were with new research, Colleen told me. Over BRC's second year, the interns went from meeting weekly to meeting every other week, and eventually only monthly. Sometimes Dr. Edwards came, and sometimes Dr. Arnold, but rarely both. The only consistent person at the

internship meetings was Colleen, who always engaged the students, and talked to them about how their projects aligned with BRC's mission. Behind the scenes, Colleen worked to integrate the interns into the evolving BRC activities. Ultimately, BRC never found a good way to integrate the interns into projects as the center developed. By the end of BRC's second year, the internship program had stopped meeting altogether.

Dr. Edwards and Dr. Arnold both cite the lack of other faculty involvement in the internship program for its failure. They could not carry the program on their own; when other faculty failed to get involved, Dr. Edwards and Dr. Arnold turned their attention to more traditional research efforts. Much of the effort of wrapping up the program was passed onto Colleen. She says that the internship program could work, but she cannot do it alone. "The commitment has to be there [from faculty] ...it was really just a matter of time for faculty to put into it. When we started [the internship program], we thought more faculty members would come too, and they really didn't. They sent their students, which was great. Without support from others, it just wasn't sustainable." Under academic capitalism, educational outreach is devalued in relation to research and related metrics of productivity. BRC-affiliated faculty welcomed research opportunities through the center but were not invested in the educational initiatives BRC took on.

The faculty shifted other educational initiatives onto Colleen as well. Early on, BRC had founded an education initiative focused on community outreach. The initiative consisted of compiling kits of items found in nature, like dead grasshoppers or helicopter seeds, to teach grade school children how to blend scientific principles with artistic creativity. Faculty considered the educational outreach program to be an important piece of their funding strategy. "[The educational initiative] will be our key to getting money

for the long term,” one faculty member said during a faculty meeting, “it will appeal to the state, and private companies will want to back it.” Another faculty member said, “BRC’s education component will hopefully draw in donors, because they’ll see that we’re helping kids learn how to be inventors, to be creative thinkers.” However, like the internship program, none of the center faculty got involved in the education initiative. Colleen was put in charge, assisted only by the one woman who was interning at the center. As more research funding came in, the educational initiative became an afterthought in BRC proposals. A few years after BRC was founded, Colleen described the educational program as “limping.” Faculty focused narrowly on research, while Colleen spent extra time on top of her paid responsibilities trying to identify more funding opportunities.

Similarly, graduate training programs also shifted educational responsibilities onto staff. I observed this in SMRT. When SMRT was initially funded, the program and its PIs were celebrated by the university. The federal program funding SMRT is very competitive, and so securing the funding was a high-profile success for the university and the PIs. Two years into SMRT, the initial program manager left, and it took roughly a year to fill the position. During that time, the co-PIs of the program refused to step in to keep the program together. The PIs would not check the program email, did not approve any required paperwork submitted by SMRT trainees, and did not keep track of trainee seminar hours. The faculty PIs leading the program, both men, acknowledged the situation was difficult but did not themselves step in to perform these duties. “It’s a lot of administrative stuff,” Dr. Keyes told students, “We are doing what we can.” The PIs were largely inaccessible to trainees. One told me he needed signatures on SMRT

requirements, so “I had to track down Dr. Keyes a couple times. I finally found him in his office. I could never tell if he was thrilled or pissed to see me [for showing up unannounced].”

Faculty scientists were resistant to stepping in and doing the housekeeping of the program, which led to disorder and confusion until they eventually found a new program manager. We know that administrative positions are framed as women’s work and that women are responsible for much of the devalued work of the lab (O’Meara et al. 2017; Hirschfield 2014). Women faculty (and faculty of color) take on more service work than their men colleagues, which ends up creating structural inequalities in career opportunities over time (Acker and Armenti 2004; Carrigan et al. 2011; Link et al. 2008; Misra et al. 2012; Winslow 2010).

Effects of Precarity on Postdocs

Research shows postdocs shoulder the instability of the academic job market while providing cheap labor in university labs (National Academies 2014; Woolston 2020). As scholars studying other precarious work note (Frenette 2013), the precarity of postdocs extends to the ambiguity of their positions. Postdoc positions are somewhat ambiguous, which means postdocs often take on different roles to different audiences. Faculty scientists often described postdocs as workers hired to move projects forward. For instance, BRC faculty weighed whether to recruit graduate students for their project or to earmark funds for a postdoc during a center faculty meeting. One faculty member says it would be smarter to hire postdocs over graduate students. “At least with postdocs,

that's their job," he says. A few other faculty members concur, including the BRC PIs. One PI says it's always easiest to "have a postdoc take the reins and run with it." In line with recent scholarship (Woolston 2020), the community recognized the exploitative nature of postdoc positions. For instance, during a meeting a faculty member explained that the NSF had recently mandated postdoc mentoring plans as, "an effort to stop the abuse [of postdocs] at some point. [Postdocs] are cheap labor. This is a part of the world we live in."

In contrast, student scientists often described postdocs as their most valuable mentors. Postdocs are likely the most senior person graduate students regularly interact with in the lab. Most graduate students met with their PIs once or twice a month, while they often saw the lab's postdocs every day (at least before Covid-19). As a result, postdocs are often the mentors who teach graduate students how to handle technical problems in their research or provide career advice. One student says the postdoc in his lab taught him how to write journal articles. Another said that, when she has a professional problem, "I talk to the amazing postdoc [in our lab]. She's super helpful, super friendly." Throughout my interviews, student scientists recalled the various ways the mentorship provided by their postdoc shaped their professional development.

Not all students had postdocs in their labs. The students who lacked postdocs were often the students that found their experiences with mentorship lacking. Brad, a graduate student, explicitly stated his lack of access to a postdoc as the cause of his inadequate mentorship:

“I came [into the graduate program] with another guy. We both got to the university the same day. Immediately, he was working under a postdoc on his project. For me, I was kind of swimming in a pool by myself, and it hasn't changed.”

Another graduate student, Carol, says, “My PI's lab is new...He doesn't have a postdoc or anything. So, there was also a lag period where I wasn't able to start research for a year...My PI is busy. He can't be teaching you how to do things.” Within academic labs, there is a clear division of labor, in which faculty manage their labs by securing funding, developing collaborations, and doing other ‘high-level’ responsibilities necessary to sustain the lab. Postdocs and graduate students perform the benchwork of the lab. Carol describes her PI as busy, someone who cannot be taking the time to teach his students everything. PIs were often inaccessible to their students. Thus, graduate students rely on postdocs for mentorship.

The close relationships between postdocs and students may have unintended consequences for the career preferences of graduate students. As I explained in my literature review, postdocs have negative views of the academic job market. They see their positions as unstable, precarious, and exploitative. Many have regrets about their career decisions (Woolston 2020). Thus, I was unsurprised that many of the graduate students I interviewed dreaded postdocs as a necessary step of the academic career ladder. However, I was surprised at how students' negative views of postdocs factored into how they envisioned their career goals. A majority of students whom I interviewed planned to go into industry careers. When asking students why they were choosing industry careers, not wanting to do a postdoc was as common an answer as wanting more

work-life balance or wanting to make more money. Students often sought to avoid the precarity of the academic career track that postdocs experience.

For instance, Adam says, “I’m...80% leaning towards [an industry career] and not doing a postdoc. I don’t want to do 60 hours a week [after graduate school].” Another student referenced the time commitment, saying an academic career was not appealing because:

“...a PhD is a long, difficult process. A postdoc just extends that... How long do you want to put your life on hold? I didn’t want to put my life on hold for as long as the PhD. And then a postdoc? I want to be doing research. Whether or not I do it in academia or industry, it doesn’t matter to me. I just...don’t want to do a postdoc.”

The time commitment was an oft-cited reason for not liking postdocs. One student says, “I don’t want to go to [academia]...because, right now, people need another three or four years of a postdoc [after their PhD] ... I don’t want to spend another three or four years...” New PhDs are working increasingly long stints as postdocs, sometimes working two or three in a row before securing a position or leaving academia. The high expectations and instability around postdocs cause a growing number of students to pursue nonacademic careers (Sinché 2016).

When I probed on graduate student distaste for postdocs, they often commented on how postdocs may affect their relationships with loved ones. One student says:

“I was so sure, so certain that I wanted to be a professor...it matches all my skills, it matches work that I enjoy...[but] after I went on vacation, I saw my long-distance girlfriend and my family that's seven hours away, and I realized...I don't have a postdoc in me...I'm feeling a little bit frustrated.”

The above student frames a postdoc position as a taxing experience, one that will take something essential out of him. Because of this, he is frustrated at the realization that he does not “have a postdoc in [him].” Another student also referenced her personal relationships when considering a career path:

“I'm not saying industry is relaxed, but I want something stable. [In academia] you work 60 hour [a week as] a post-doc. I don't want to do that. I'm past that point. I've been in a long-distance relationship for a while. I don't want to have to make that more strained than it is. As cliché as it is, I want to settle down. I don't want to [be]...stressed out all the time...I don't mind working hard. I don't mind challenging myself. In industry, I'll still be able to have that chance... I want to focus more on settling down with life and living life versus constantly working...”

These findings highlight how precarious work stretches beyond the workplace, having potentially negative social repercussions for precarious workers (Pugh 2015; Pugh 2021). As postdocs mentor student scientists, students may be learning more than technical expertise. They may see how hard a postdoc can be, how social relationships may suffer, and decide a nonacademic career would better suit their life.

Effects of Precarity on Graduate Student Scientists

Like postdocs, graduate students face a precarious labor market following their PhDs. STEM job market insecurity is heavily shaped by the changing labor dynamics of academic science (Stinche 2016). In recent decades, industry has become an increasingly legitimate career path for new PhDs (Smith-Doerr 2005), especially as academic science has become a less secure career path. Despite the changing career goals of students, academic science has traditionally trained students to pursue academic jobs (Hagstrom 1964; National Academies 2018). Some students critiqued aspects of their training for being too focused on preparation for academic careers when that was not what they wanted. For instance, students shared a desire for SMRT to facilitate more industry connection in focus groups held by the external evaluator of the program. SMRT trained students to communicate with industry audiences, but students sought more direct connection to companies. In another example, I attended a class titled “Scientific Management,” a required course that trained students to be future PIs. It taught them how to manage labs, fundraise, network, and build a strong tenure portfolio. Students found the class useful, though some students critiqued it for focusing too much on academic career trajectories.

Rather than accommodate the changing professional needs of student scientists, university STEM programs have adopted strategies that shift job market and educational responsibilities onto students. The clearest example of this market and educational responsibility shift onto student scientists is the IDP developed by the university and mandated for SMRT trainees. The IDP is:

“...a comprehensive roadmap designed by the student in consultation with a mentor that plans courses, professional development activities, training experiences and a research agenda for that student. A living document that includes all elements of the SMRT program, the IDP will be revised annually as the student progresses...

“[The IDP serves] as a planning and personal management tool for the student’s use in charting their specific traineeship pathway leading to a career area of interest to the Trainee; as a channeling mechanism for bringing student research plans into alignment with SMRT’s research concentrations; and as a framework to facilitate more effective and more comprehensive mentoring” (SMRT planning documents).

The IDP provides a tool for students to chart their specific pathways toward their desired careers. An SMRT faculty told trainees that: “[The IDP] is a forward-thinking document...students just have to look at [the IDP] from the beginning and know, ‘these are the things I should be doing.’” The IDP reflects the audit technologies used by universities to manage faculty. Through the IDP process, students are socialized to be self-governing and entrepreneurial. This shift allows university faculty and administrators to recede into the background, focusing on more institutionally valued activities while students chart their own courses to desired careers.

Throughout my years of fieldwork, I found several instances of faculty using IDP-type practices in their labs to manage their students. One faculty member had come to the university after a long industry career in a Fortune 500 company known for its

“management tricks” to boost worker productivity. An IDP system was one such trick. When the faculty member started his academic job, he used an IDP to manage his students. The faculty member’s IDP had numerical scales for students to rate their perceived strengths and weaknesses, and opportunities to outline research goals, target conference presentations, and list professional ties they would like to develop. He says: “When I came here...I used a review process, a development plan, but it wasn't as [rigorous]...specific, or tailored as the IDP...we had at [Fortune 500 company] or the IDP we are using in SMRT.”

Other faculty members implemented IDP-type practices as well. One faculty scientist described the IDP in his lab:

...as an annual progress report...We have an annual faculty report that we turn in... [I have] this annual performance review for my students. I instituted this because I thought that it was really helpful. My first exposure to [the IDP] was my wife, who works for a big company. She had to do it. I thought the process by which they did it was really good, and so I instituted that.

The faculty scientist describes his version as “more industrial” than the IDP used by SMRT: “My version is more like a list of questions. I don't think it's quite as directed as the IDP [used by SMRT]. I think in principle they're basically the same thing, but the mechanics of them are a little bit different.” Another faculty has her students submit weekly progress reports: “They say what they did last week, what they are going to do next week”, as well as monthly goals. Then once a year, she meets with her students to lay out long-term goals, revise the goals laid out the year before, and revise plans.

SMRT included an IDP system in their funded NSF proposal. When deciding on how to implement an IDP, SMRT faculty reviewed three different options as a group. They reviewed a model IDP developed by the American Association for the Advancement of Science (AAAS), which universities and programs can purchase. They also considered an IDP that one of the SMRT faculty members used in their lab. But they finally went with an IDP model developed internally by the university at the graduate school. One of the SMRT PIs told trainees that, “five years from now...every graduate student [at the university] will have an IDP... [SMRT is] leading the charge here.” During early meetings, the SMRT PIs excitedly tells trainees they were “beta testing” the university’s model, and their experiences with the IDP would have educational implications for future students at the university.[2]

The university communications about the IDP with SMRT trainees reflect the responsibility shift processes underway through these audits. During a university-led workshop, the administrator leading discussion told trainees the IDP would enable them to “take ownership of [their] path through a process of self-reflection, assessment and goal setting.” By formalizing the IDP process, the university would help students facilitate conversations with their advisors, “allowing [student scientists] to verify expectations and seek feedback and guidance for career progression.” With the IDP, student scientists create a roadmap for their “long term goals, short term deliverables, progress milestones, and career development,” the university representative told students, adding the IDP would help them identify paths to “resources, strategies, and mentors for targeted research and career goals.” At a different meeting, an SMRT told students the IDP would empower students. He said: “Almost all the bad stories you hear about

graduate school deal with a lack of power on part of the students. That is why I like the IDP... maybe it's a way to help manage your PhD career, but it can also...empower the students a little more.”

SMRT trainees submit IDPs annually, a process which facilitates regular check-ins between students and their PIs. After filling out their IDP, trainees must have their advisors sign off on the document before it is submitted to an SMRT faculty advisory board for approval. In the IDP, trainees record their professional accomplishments from the past year, and professional goals for the coming year. Trainees record any presentations, manuscripts, grants, fellowship applications, honor, awards, data collected, or conferences attended.

During an early meeting with the first cohort of SMRT trainees, the PI explains that it is okay if students rate their strengths and weaknesses differently than their advisors. In fact, the IDP process can be a useful tool for facilitating necessary conversations between student scientists and their PIs, he says (see Figure 2.1). In interviews, students often raised the issue of mismatches between how they saw themselves versus how their advisor had evaluated them. One student says: “My answer was slightly different than my PI's... I thought I was more independent, and she thought I was less independent. But then I was talking about some of the things we did, and then it was helpful to see how I'm viewed. [The IDP] helps you self-reflect, in a way.” Another student says:

“[The IDP] was nice, as in, having a discussion [with my advisor] really helped me identifying my strengths and weaknesses... [The IDP] helped me identify

what skills I need to improve based on that career I want to go for... It really helped in terms of setting goals and identifying strengths and identifying weakness that I need to improve on.”

During interviews, students often described how they had rated themselves higher than their advisors on things like research skills or independence as a scholar, which then provided students with a moment of reflection. The IDP facilitates an interaction in which the metrics of where a student *should* be, like ‘independence’ are made explicit. These metrics are the qualities students should display to be competitive on the job market. Students then can correct these shortcomings to become more competitive on the market, it is implied.

Some SMRT trainees praised IDPs for helping them plan their careers and facilitate conversations with their PIs. One student named Rory said the IDP got her to think about her future self in relation to the work she is doing now:

“I loved [the IDP] ...I'm glad that I did it and I'm excited to continue doing it. I liked how it made me think about [my research], in terms of how it affects me. Future me. When I think about what I'm researching, I usually think about the future of the project. It's nice to think, ‘Oh, well what's the future of me in relation to the project?’ and then we'll both grow together.”

Rory “loved” the IDP because it helped her envision her potential career in the work that she was currently doing. Rory added that: “My PI hadn't been very involved, so it was a nice subtle way to facilitate communication about these things.” In some cases when a student was not receiving adequate mentorship, the routine check-in facilitated by the

IDP created opportunities for important conversations for student's professional careers.

Another student named Liz, says:

I personally love [the IDP]. I wanted to do [an IDP] because I wanted my PI and I to be on the same page...my meeting with my PI, where I showed him my IDP ended up being like...what did I want to get out of [the IDP process]? We talked about that. The most important part to me was the timeline because...I need deadlines... that's just how I work. The IDP was helpful to me. I [also] thought there was something about the assessment of strengths I thought was nice to go through [with my PI] as well.

Liz describes the IDP as a process that helps her create structure for her graduate career and set mutual expectations with her PI. For some students like Liz, the IDP can facilitate a process of setting expectations for students, which helps them understand how to be successful.

Other SMRT trainees found the IDP to be less helpful. For instance, Doug said the IDP process was not something he felt he needed:

“Have I looked at the IDP since I've made it? No. I've always just pushed myself to get as much stuff as I can done as possible. I don't feel like [the IDP is] necessary for me to keep track of where I am. When I did it I realized I was on track with where I thought I should be. Same thing with my PI. He was like, ‘Yeah, for where you're at right now and for what I wrote down.’ [The IDP is] a good concept but I don't really think I need it.”

Doug felt that the IDP process just gave him information he already knew, and as a result felt no need to consult it. Instead, he knew he should just be pushing forward to be as productive as possible. Many students felt the IDP just added to their already heavy workload. One student said: “Filling it all out is tedious, but maybe it's something you have to do to get the benefit from it?” Another student said the IDP “is pretty intense. It’s a lot of work to do.” A third, Gordon, said the IDP:

“...wasn't that helpful. Maybe [it could be] for other people, but not for me. I kind of know what I'm here for ... It would definitely help some people at least start the discussion with like, ‘Why am I here? Am I being productive enough?’ But I don't know, I think I have a pretty good grasp of that, so doing this type of thing is really just more work than benefit.”

Like Doug, Gordon reflects that he already knows how productive he needs to be, and thus the IDP is not that helpful. Several trainees did say that the IDP could be useful for students new to the STEM PhD process. But students even in their second year of graduate school felt they knew the rules of the game, and thus doing the IDP was not actually beneficial.

Several student scientists resisted the implementation of the IDP. Early on, SMRT PIs emphasized that the IDP, “is not an evaluation tool,” but rather a tool to help students develop necessary skills, set goals, and identify pathways to achieve those goals. However, a report compiled by SMRT’s external evaluation team revealed that several students were confused or uncomfortable with the IDP. Many students had decided not to

fill it out. In response, the PIs called a meeting with students to inform them the IDP was mandatory:

A student raises his hand, “I thought we were beta testing [the IDP],” he says. Dr. Lipton shrugs. He explains that he uses an IDP with the students in his lab as an “annual performance review...[that] gets students more engaged in the management of their PhD. That’s what I like about it.... I am against busy work, but I think the IDP is extremely useful.”

“From the evaluations, students don’t like it,” says Dr. Keyes. The students are silent.

Dr. Lipton shrugs. “We want you all to have an IDP. In fact, after [the first cohort of trainees], the IDP is required if you want to qualify for [SMRT] funding.” This new information stirs a reaction from the students, who begin talking amongst themselves.

“You shouldn’t be looking at the IDP as a burden,” Dr. Keyes says. He emphasizes the IDP will “help [them] move forward” with their professional goals.

Another student raises a hand. She says that she felt the IDP was being forced on her too early. “I’m in my first year, I just finished [qualifying exams]. A lot of this stuff isn’t relevant to me yet.”

“It’s never too early to be proactive about your career,” Dr. Lipton replies.

“Right,” Dr. Keyes says, “the things that don’t seem relevant are things that you could have fresh in your mind” (Fieldnote excerpt).

Faculty threaten to cut the funding of trainees refusing to participate in the IDP process. Despite the concerns that students raised over the IDP, the SMRT PIs pushed forward with the system. Throughout my five years of fieldwork, SMRT faculty emphasized how the IDP would help students take ownership of their careers. Students continued to have mixed reviews of the IDP system in external evaluator reports, but it remained a requirement for SMRT funding.

DISCUSSION AND CONCLUSION

In the entrepreneurial university, faculty scientists, academic staff, postdocs, and student scientists all experience responsibility shift in different ways. The structural dynamics of each position allows universities to benefit from their labor while these precarious workers shoulder their own job market burden with little training or support. The pay structure of academic staff is highly insecure, giving them little security when the programs they manage are unable to secure funding. Thus, staff shoulder much of the responsibility not only for the devalued housekeeping of these programs related to education and diversity goals, but also shoulder personal job market burdens when they are unable to secure adequate funding. Postdocs shoulder the insecurity of the academic job market while providing skilled but also cheap labor for academic projects (Woolston 2020). To some degree, both staff and postdocs are ambiguous roles, which allows them to become a catch-all for devalued work. I find that this shift in responsibility to marginal

workers includes education activities under academic capitalism. Findings show that educational initiatives in academic science programs are often passed off to staff while faculty focus on meeting formal measures of research productivity. In academic labs, postdocs take on the important role of mentoring graduate students while faculty manage the lab at the organizational level.

Similarly, student scientists are expected to navigate the precarious job market themselves, identifying the skills they need and how to develop them. I find that universities shift market and educational responsibilities onto students while framing these responsibilities as taking ownership of their career goals. The use of audit documents by the university to govern students' education mirrors neoliberal governance strategies that emphasize individual autonomy, through which the expectation of individual responsibility arises. As Wendy Brown writes, neoliberal governance deploys the "human capacity for responsibility...to constitute and govern subjects, and through which [the subject's] conduct is organized and measured" (Brown 2015: 133).

This chapter contributes to sociological theory on precarious work and responsibility shift. I demonstrate that the responsibility shift experienced by staff, postdocs, and students unfolds in tandem with university efforts to make faculty scientists more productive. Staff, postdocs, and students are all marginal in relation to academic faculty, but they are all ancillary workers to the research objectives set by the university. Staff complete grant 'housekeeping' that includes activities that are formally PI duties like report writing, and leading educational and diversity efforts. The two PI pairs whom I observed for this research were men. Misra et al. (2021) show that women tend to take on more academic service work while men spend more time on research. These gendered

dynamics may have been exacerbated in the cases I observed, as both the center and traineeship program had men PIs and women staff. We need more research on the labor of academic staff in the research process. This should include an intersectional analysis to understand how these devalued positions are gendered and racialized.

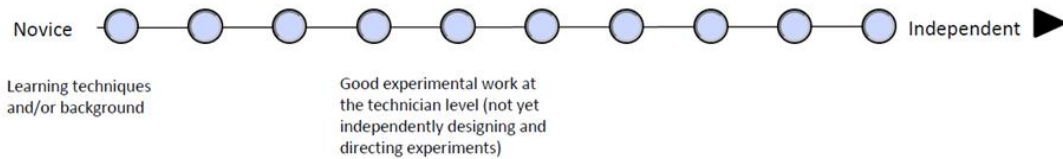
In the eyes of faculty scientists, postdocs are responsible for managing the day-to-day dynamics of a project, while graduate students complete most of the benchwork to support the goals for funded research set by the university. Academic staff, postdocs, and graduate students are subject to responsibility shifts that support university goals, either directly or indirectly. By cutting a program's staff when it is unable to secure funding, universities stay as lean as possible, making them adaptable to market fluctuations. Postdocs, facing an unstable job market, provide skilled work to university science while receiving little long-term security. Students face the same job market insecurity and are expected to blaze their own paths forward to the careers they want. The marginality of staff, postdocs, and students, leaves all three in positions to take on devalued educational responsibilities while faculty stay focused on research.

[1] I am focusing here on the experience of grant-funded staff rather than the experience of permanent staff, who are supported by the university. Grant-funded staff are temporary or limited-term positions that are only supported for the funding period.

[2] As of the end of my 5 years of observation, IDPs have not yet been widely implemented across graduate programs, perhaps reflecting change in leadership at the graduate school.

CHAPTER 2 FIGURES & TABLES

Figure 2.1: A screenshot of the layout of IDP with sample prompts.

3. Indicate where you feel you are on the continuum of becoming an independent researcher. You may be in different places in regard to different parts of your training; how do you feel you are doing overall?	
	
4. Advisor Comments (Narrative describing advisee progress and goals)	

CHAPTER 3: TO BE OF VALUE: HOW STUDENT SCIENTISTS MAKE SENSE OF INTERNSHIPS

BRC had little financial support during the first year of its existence. One of its PIs described BRC as “like a startup, without the millions in equity.” To make up for this funding shortage, BRC PIs decided to recruit “promising undergraduates” from the labs of affiliated faculty to intern with BRC in exchange for course credit. As the PIs worked to develop a prototype of a new wig adhesion technology, the interns conducted patent searches to understand who their competition was and identify shortcomings of the designs of their products. Interns visited local wig retailers and scoured online message boards dedicated to wig-wearers to identify “the pains of the market.” PIs asked interns to identify the common complaints of wig users to better understand what issues they could address. PIs had interns run experiments on adhesives, and even had interns draw prototype ideas for what BRC’s new technology could look like. BRC secured its first external grant presenting on work that had been done by their interns.

Internships are a “practical educational experience whereby an intern learns by working at a host firm under varying degrees of supervision” (Frenette 2013: 365). Across sectors, internships are increasingly common for young professionals trying to gain a foothold in the precarious labor market (Bailey et al. 2004; NACE 2011; Smith 2010). The scientific field is no exception. Researchers estimated that between 60% and 75% of all U.S. undergraduate students hold at least one internship before graduating (McDermott 2013; Perlin 2011). In popular culture, internships are lauded as opportunities that will help young professionals grow as professionals and become more competitive on the job market (O’Neill 2011). A *Science* editorial encouraged students to

seek out internships to help “get past the frustration [of research] ...and in the process [learn] how real research differs from science learned in the classroom” (Pain 2008).

However, others critique internships as yet another mutation of neoliberal ideology in higher education. The modern-day internship rose in prominence in the late 1970s, running parallel to broader economic trends that stripped away worker protections in favor of profit (Neff and Arata 2007; Perlin 2011; Figiel 2012; Hope and Figiel 2012; Daniel and Daniel 2013; Seibert and Wilson 2013; Percival and Hesmondhalgh 2014; Ashton and Noonan 2013; Chillias, Marks and Galloway 2015; Shade and Jacobson 2015). Internships are temporary, lacking real job security, and interns are often paid less than permanent employees, if they are paid at all.[1] On a structural level, interns provide cheap labor that has “quietly replaced or displaced thousands of workers” in recent decades (Perlin 2012). Interns are also flexible labor. There is very little uniformity across intern experiences because host firms tend to deploy intern labor where it is needed (Frederick 1997; Frenette 2015). In some sectors of the economy, interns take on these precarious jobs in hopes of finding more permanent employment through the position. For instance, Frenette (2013) found that music industry interns sought to secure more stable work through their internships, though it was rare for interns to leverage their positions to more secure employment within the record companies.

Student scientists pursuing STEM PhDs are not usually trying to leverage their undergraduate internship to gain permanent employment because they plan to attend graduate school. And unlike standardized tests, internships are not a formal prerequisite for admissions into a STEM graduate program. In other sectors, internships are framed as apprenticeship-like experiences that professionalizes students for their eventual

profession (Frenette 2015). However, in science, the PhD program is itself a five-year long apprenticeship; while taking courses, graduate students work in the labs of academic faculty, often their thesis is part of a larger project that supports their advisor's research program. Novice scientists have long been professionalized through these apprenticeship-like PhD experiences (Hagstrom 1965; Zuckerman 1977). If internships are recognized as exploitative, and student scientists are already expected to work long apprenticeships for professionalization, why do student scientists take internships? How do they make sense of their position as interns? My study of internships focuses on student experiences and perceptions.

Critics also argue that universities abet the exploitation of internships, often offering students course credit in lieu of payment from host firms. Some universities have gone so far as to mandate internships (McDermott 2013). In line with Chapter 3, scholars have cited internships as a case of how universities shift educational responsibilities onto students (de Peuter et al. 2015). But we need more research into how the STEM internships are tied to broader shifts toward academic capitalism. In this chapter, I ask: 1) At what stages of student scientists' educational paths do they take internships, and why? (2) How do student scientists make sense of their internship experiences in the broader context of their professional training? (3) How are universities involved in students' decisions to work in internships?

I find that normative and coercive social pressures shape undergraduate student scientists' decisions to pursue internships. In my sample, all but two students who had completed their undergraduate degree in the U.S. had worked in an internship before graduate school. It was less common for graduate students to take internships, although

graduate students pursuing industry careers often sought internships to help their job prospects. I find that undergraduate and graduate students understand their internship experiences as adding to their value as a worker. I draw on the science and technology studies (STS) theories of asset construction to understand how students make sense of their internship experiences (Birch and Muniesa 2020). Student scientists entering the field are competing with others for resources, whether funding from an academic lab or an industry position after completing their PhD. Internships are not mandatory prerequisites for graduate school or permanent industry employment but have taken on a credential-like quality because everyone has had them. Internships vary in quality, and thus represent a case of risky credentials in which students engage in credentialing situations that may not pay off (Cottom 2017).

I observe that university framing of internships for both undergraduate and graduate students reveal processes through which entrepreneurial universities have commodified student scientists. At the undergraduate level, universities have increasingly become involved in facilitating undergraduate internship placement. Universities, increasingly driven by metrics (Espeland and Saunders 2016), compete for measurable outcomes like undergraduate job placement for career preparation. Internships look great on these measures which are used to increase undergraduate applications. In the process, interns fill flexible labor needs for host companies. Internships often vary in quality, but that doesn't really matter for the statistics on the university website. These positions look good for universities, and they are good for companies. At the graduate level, students saw internships in a similar way, and assumed internships would increase their value. At

the undergraduate and graduate level, student labor is being commodified by the university in different ways.

PROJECTING VALUE IN THE KNOWLEDGE ECONOMY

This chapter draws on theories that explain neoliberal models of ‘human capital’ and ‘credentialism’ in higher education (Collins 1979; Cottom 2017), commodification (Marx and Engels 1978; Polanyi 1944; Burawoy 2003), and asset construction under technoscientific capitalism (Birch and Muniesa 2020; Kang 2020; Roy 2020) to understand the structural conditions around STEM internships and also how student scientists make sense of their internship experiences. Below I argue that student scientists understand their internships as part of a broader process in which they develop human capital, accumulate valuable credentials, and thus construct themselves as assets that could yield future economic gain for PIs or employers. At the same time, my analysis of STEM internships reveals processes that commodify undergraduate and graduate students in different ways, most of which are unseen by students. Together, these theories provide a framework for understanding the academic capitalist conditions that shape the internship experiences of student scientists. My work fills an important gap by examining how students experience and exercise agency under these structural pressures of academic capitalism.

Human Capital and Credentialism

As I discussed in Chapter 2, one manifestation of the neoliberal reorganization of society are processes that shift job market responsibility onto individuals. One way this process has played out within the field of higher education is the diffusion of a human capital model of education that centers individual competitiveness (Brown 2015; Sawyer 1978; Walters 2004; Holden and Biddle 2016). Human capital theory posits that individuals gain unique skills and experiences that set them apart from other applicants. Business scholars have championed ‘human capital’ as a key resource for both individuals and organizations in the contemporary economy (Barney 1991; Becker 1964; Coff and Krysinski 2011; Ployhart and Moliterno 2010). For economists, human capital has been a useful empirical concept for understanding the value of a person by measuring the ties between their professional experiences and income. In the new economy, organizations compete for human capital to gain economic advantage (Peteraf and Barney 2003; Powell and Snellman 2004). However, critical scholars argue theories of human capital “are *themselves* profoundly capitalist, insofar as they remake the subject in capital’s image” (McClanahan 2017: 514).

Universities encourage students to pursue professional experiences like internships to gain marketable skills, i.e., their human capital. I argue that, in part, universities have metrics in mind when they push students to take internships. As I discussed in Chapter 2, universities are increasingly focused on rankings (Meyer and Bromley 2014; Espeland and Saunders 2016). Universities pay particular attention to the rankings published by U.S. News & World Report, a media company that publishes consumer rankings and analysis of a variety of products but is mostly known for college

rankings. An editorial in *Nature* critiqued university rankings for being “unfair and irresponsible”, prioritizing measures like faculty prestige or student extracurriculars over measures like equity, sustainability, or collaboration, or whether a university is living up to its mission (Gadd 2020). An important measure in university metrics is student employment following graduation (e.g., Kowarski 2021). In a context in which this human capital frame is dominant, schools aim to develop institutional systems that will help students be competitive on the market by accumulating human capital. U.S. News & World Report also ranks universities specifically on their institutional capacity for career preparation, including specific metrics on internship placement (Boyington and Moody 2020).

Below, I show that as universities push students to find internships, they frame these positions as invaluable “real world experience” that will give students a competitive edge on the market. During interviews, students laud internships for providing real-world experiences that were lacking from their formal educational program. Frenette (2013, 2015) found that music industry interns often framed their internships as providing real world experience, despite the extreme variation of internship quality on the ground. Similarly, while student scientists have a somewhat cohesive frame in how they discuss their internship experiences, there is a lot of variation across internship experiences. Like other precarious jobs, there is ambiguity to internships. Interns are flexible labor, and organizations use them as such, deploying interns wherever they were most useful. Thus, some students gain invaluable experiences working independently, or collaborating on research, or even working on a commercial project. Others set up the food and tables for company meetings, took inventory, and completed other “mindless tasks.”

I find that students treated internships as another credential to be acquired. Sociologists have long studied the dynamics of credentialism in society, in which workers accrue academic qualifications or certifications to become eligible for certain jobs (Johnson 1972; Klegon 1978; Collins 1979; Abbott 1988; Brown 2001; Khoo 2019). However, what is interesting is that internships are not formally required for graduate school. The faculty members in my study expect their students to have academic lab experience as an undergraduate; internships were never bad, but also not necessary. None of the faculty in my study required students to have internship experience as a prerequisite for working in their lab as a graduate student. Internship experience is not a prerequisite for applying to graduate school. And unlike other sectors (e.g. Frenette 2013; Frenette 2015), student scientists do not expect their internships are going to lead to more permanent employment.

I find that students understand their internship experiences as part of a process in which they construct themselves as assets in which future employers (an academic PI, an industry firm) should consider investing. But in this process, students may or may not actually get anything out of their internships beyond the credential. Thus, I argue that STEM internships reflect the risky credentialism Cottom (2017) theorizes in her analysis of the growth of for-profit colleges. Companies once had internal systems in which to train new employees. As companies have increasingly focused on efficiency and profit, they have shifted training responsibilities onto prospective employees. Prospective employees must find their training experiences at their own expense, in the hope that their investment in the training will pay off in a more stable job. Cottom highlights how entry-level credential requirements have become increasingly common for less skilled

and more mundane work. This shift in training responsibility has pushed potential employees to seek out credentials through for-profit institutions. Cottom argues that these are risky credentialing contexts that often do not pay off for students.

Similarly, I find that STEM internships are risky in the sense that, while all students worked internships, not all internships paid off. While some interns have fulfilling internship experiences, others are relegated to getting coffee or food for meetings, inventory, or other mindless tasks. It is often difficult for students to know what the quality of their internship will be before they take it. However, the student scientists I study worked internships as undergraduates even though internships are not required for graduate education or for future work in industry. Student scientists engage in internships in a credentialing manner (at the undergraduate level, anyways), but there is no formal requirement for internship experience. Why are student scientists engaging in internships if these positions may or may not provide meaningful experience?

Commodification

My analysis of internships reveals various processes of commodification under academic capitalism. Commodification, “the defining experience of capitalism” (Burawoy 2003: 211; Lukacs 1971), is the “subordination of both private and public realms to the logic of capitalism. In this logic, [noneconomic things] are understood only in terms of their monetary value. In this way, they are no longer treated as things with intrinsic worth but as commodities” (Felluga 2021; Marx and Engels 1978). A classic concern in Marxist theory has been growing commodification of labor as capitalism has

diffused across the globe. The growing commodification of labor has led to growing instability and less cohesiveness for workers (Polanyi 1944). As Gramsci (1971) argued in his theory of hegemony, institutions like education legitimate processes of commodification for workers.

Theories of academic capitalism assert that the entrepreneurial university reimagines students as commodities (Slaughter and Leslie 1996; Slaughter and Rhoades 2004). For instance, Slaughter et al. (2002) argue that PIs use their graduate students as ‘tokens of exchange’ in collaborations with new industry partners. Students act as symbols of good faith, traded for valuable resources in these collaborations. Slaughter et al. (2002) reveals that, at least in certain contexts, commodification is a central experience for students. Slaughter and colleagues focus on how faculty think about their students, but students’ interpretations of their conditions were absent from the analysis. This chapter fills a need for understanding the commodification of graduate students under academic capitalism, from the perspective of the students.

Universities promote internships to undergraduates because they help universities meet metrics around career preparation. Industry benefits from the seemingly endless supply of temporary labor. My study also reveals the impact of internships after the undergraduate degree in the processes of commodification for graduate students. Graduate students often expressed a desire for internships but rarely took them, because internships came into conflict with the work expectations PIs have of their graduate students. Faculty scientists are under enormous pressure to produce (Shore and Wright 2000; Slaughter and Rhoades 2004), and thus when they bring a graduate student into their labs, they expect that student will be working for them year-round until they have

their PhD. By analyzing tensions around graduate internships, this chapter highlights how graduate student labor is commodified in the normal academic lab hierarchy.

Internships and asset construction

I find that student scientists make sense of their internships as experiences that will increase their human capital, thus raising their value in competing for job positions. Some students describe their internships as a broader process of constructing themselves as assets in which future PIs or employers would consider investing. STS scholars have theorized the “transformative character of turning things into assets” under technoscientific capitalism (Birch and Muniesa 2020: 4). For instance, patents, key outputs in the knowledge economy, are the end product of a construction process that turns new knowledge or novel technology “into speculative financial assets” (Kang 2020: 45). The patent is the legal protection of new knowledge deemed valuable. It costs money to patent knowledge, and thus not all novel forms of knowledge are patented. It can cost tens of thousands of dollars for a university to patent a novel technique or a new piece of technology. In that process of deciding what is patented, knowledge becomes an asset. Similar processes go into constructing other types of knowledge into assets as well (Beauvisage and Mellet 2020; Roy 2020).

Skilled knowledge workers are important assets in the knowledge economy (Powell and Snellman 2004). We can see this valuation in how academia and industry compete for newly minted PhDs (Kleinman and Vallas 2001: 470). Within academia, tenure has become harder for junior faculty to attain in recent years (AAUP 2018). As

discussed in Chapter 2, universities employ audit technologies and other management strategies to push academic faculty to produce more and at faster pace (Espeland and Saunders 2016; Shore and Wright 2000; Strathern 2000). We can interpret these behaviors as universities pushing faculty scientists to perform in ways that add value to the investment over time. Similarly, I find that student scientists understand their internships as part of a broader process by which they construct themselves as assets. These findings reveal that students' understanding of their behavior aligns with the broader economization of academic science (Berman 2012).

DATA AND METHODS

A *Science* career advice column once lauded internships as a good opportunity for those deciding whether they wanted to go to graduate school because it would give them experience with real, hands-on science (Pain 2008). In internships, students would learn to approach work “with rigor and integrity,” thinking through experiments, keeping a lab notebook, and to enhance one’s learning “by interacting with people other than your supervisor” (ibid). If students liked their internships, then graduate school may be for them.

I open with this column because it gets at a sampling bias issue that undoubtedly shaped my findings. All the students I talked with pursued graduate school, and so I can only speak to STEM internships among this subset of students. Some respondents describe the experiences of acquaintances they knew who had taken internships and found permanent employment through their experience. They also shared stories of

students who, after working in internships, left the field entirely. I cannot speak to the experiences of these students because I did not interview them. My data only touch on those who had internships and then pursued a graduate STEM education.

I did observe the BRC “internship” program described at the beginning of this chapter from January until December of 2015, sometimes multiple times a week.

However, my observations at BRC, an academic research center, were not a typical industry internship as described by my grad student respondents. The PIs of BRC once described the center as “like a startup without millions in equity.” It was very market focused. But still, it was housed in a university. Thus, my observational data speak to academic capitalist contexts, but not industry contexts directly.

FINDINGS

In this section, I address when and why student scientists work in internships. First, I outline the similarities and differences between undergraduate and graduate internships. Then, I analyze students’ narratives around internships as providing real world experience. I examine the (risky) credentialism that occurs through internships. Finally, I break down processes of meaning making, understanding internships as part of a broader process of students constructing themselves as assets.

Undergraduate and Graduate Level Internships

All but two students whom I interviewed (and had completed their undergraduate study in the U.S.) had worked in an internship before coming to graduate school. Many student scientists had worked in more than one internship as an undergraduate. A few students had worked in academic internships for programs like the National Science Foundation ‘Research Experiences for Undergraduates’ (REUs) or staffing a university research institute. Others worked in public sector internships with defense agencies or at national laboratories. However, most students had their internships in industrial firms. In conversation, students and faculty often equated ‘internship’ with the private sector. For instance, one student says, “I’ve met people who have worked [STEM] internships... [they are] usually all based out of some company. It’s specifically referred to as like, ‘Oh, I’m an intern at this company.’ To me, ‘internship’ is loaded with all these extra meanings that revolve around corporate and private sector industry.”

Written work highlighting the exploitative nature of internships are often talking specifically about unpaid internships (Mayo and Shethji 2010; Perlin 2011; Footman 2012; Pope Sussman 2012). All students who had internships in my sample had been paid for their labor. Very few students said they found an internship because they needed money. Rather, normative pressures drive student scientists to pursue internships. One student described applying to several internships at a time to cast a wide net: “Everybody was applying,” he says, “Not everybody got internships, but everybody was aiming for one.” Internships are a source of competition between students. The two US educated students without internship experience in my sample had both applied to several internships, from which they had been rejected. “I got rejected from all [the internships

for which I applied]. I applied to eight last year,” one student says. Students consider internships as important to their professional development. One student had a graduate student mentor who emphasized, “[an internship] is what...to do” if he was going to apply to graduate school.

Increasingly, universities help undergraduate student scientists find internships. “My [academic program] really encouraged us to get internships...” one graduate student recalls. Another said, “My undergraduate advising office did a fairly good job of letting the students know...[about available] internship opportunities.” Some students attended university-sponsored internship fairs to find an internship that felt like the “right fit” before applying. Past scholarship demonstrates that, in the U.S., workers have an individualized understanding of their labor market experiences, and the idea of finding the right fit is important (Sharone 2013a; Sharone 2013b). Other students attended university-sponsored workshops that helped undergraduates write internship cover letters, format resumes, and develop interview skills.

A few student scientists attended undergraduate programs that mandated internship experience. One student scientist completed an undergraduate program that mandated six months of internship experience, or the equivalent of two summers of private-sector labor, to graduate. One such undergraduate program described its mandatory internship:

“[Internships] ensure students are on the path to achieving their education and future-career goals...[bridging] the gap from education to employment...[enabling] undergraduate students to balance classroom theory

with practical, hands-on experience prior to graduation. Students alternate classes with full-time employment through University-approved employers...”

In Chapter 2, I show that universities are shifting educational burdens onto students. The push for undergraduate internships is another example of this responsibility shift process. Universities frame internships as an opportunity for students to take ownership of their education to secure their career goals. Attending a program that mandates internship experience ensures you have institutional support to find these positions in a field where everyone is competing for one. Schools that mandate internship experiences may also have stipulations that increase the quality of the experience, but this was not something I observed.

In contrast with undergraduate-level internships, graduate-level internships were less common for student scientists, in part because graduate internships conflict with the labor expectations STEM faculty have of their graduate students. Universities have increasingly used audit documentation practices to push faculty to be more productive (Shore and Wright 2000), which in turn affects graduate training. Academic faculty manage their labs by developing collaborations and securing funding, but they rely on graduate student labor to ensure funding the lab will meet evaluative milestones put in place by the university. Several graduate students wished they could take graduate internships, but the commitments required of the position often conflict with expectations of their supervising PIs.

During one SMRT meeting, faculty discussed student dissatisfaction with certain aspects of the program. Students had told the program evaluator that they were not

getting as much industry connection as they had hoped. One faculty member proposed mandating industry internships for trainees to help facilitate this desired industry connections. “Companies would like it, and students would, too,” another faculty member says. But not everyone was in favor. Some faculty opposed graduate student internships because they would mean lost labor for the faculty. “[If students work in summer internships], we are losing three months of really productive research, that’s just down the tubes,” one faculty member complained. “Right,” another replied, “Companies will love this. The problem is the faculty.” Another faculty member says: “Companies want this. Students want this. It’s us that will have the problem.” The group decided that, if students want internships, they must communicate that desire to their PIs early on. Then, instead of faculty losing three months, they could push their students to “ramp up productivity” and accomplish twelve months of work in nine months, giving students three summer months for an internship if that was really what they wanted. “[Getting students to do] ...fifteen months of work in twelve months,” another faculty member reiterated, “it’s doable, but it would take some coordination.” Perhaps because of the lack of incentives for faculty, the internship idea was dropped and the idea of coordinating internships within the SMRT program fell through.

Often, traineeship programs like SMRT provide graduate students with internship opportunities in ways that also benefit their PIs. Benefits often took the form of student funding for a year or more, which then temporarily relieves the PI of pressure to fund the student. Of the three federally funded traineeship programs at the university, SMRT was the only one that did not offer internships to trainees. This lack of opportunity was a major student critique of the program. One student says “the thing that would [improve

SMRT] for me personally...is having the opportunity to have a summer internship of some kind of working within industry. I was really hoping that [SMRT] could somehow coordinate that.” Another wanted to bring in more industry people, “...then we could go and talk to them... People [from industry] could come in and give lectures if they know they have internships coming up, and then [SMRT] can make it link up.” A third student says, “I think the single thing I would like to see is industry opportunities and internships...incorporated more throughout [SMRT].” A fourth student tells me he was applying to one of the other traineeship programs at the university, “...because one requirement is getting an internship position. They set you up with that ...If I can get an internship and then get out of the program I’d be in a really good spot.”

Despite faculty resistance, the university often encouraged graduate students to find internships to be competitive on the job market. For instance, at a workshop hosted by the university for SMRT trainees, the university administrator told students that internships are “a great idea,” to gain “real world experience” and maybe even a “competitive edge on the market.” From the back of the lecture hall a student raises his hand. “You know, the biggest problem with internships is convincing your advisor you should disappear for three to six months,” he says. The other students in attendance laugh. The administrator replies that internships are a “valuable experience,” but only for “extended periods of time...a two-week internship in a company is a waste of their time and resources, they need you to be there for an extended period of time, producing something.” She acknowledges the commitment of an internship “might not make sense for everyone,” and that was for students to work out with their PIs.

“An internship is like the real world”

Below, I show that students consider their internships to be valuable because it gives them real world experience, by which they mean experience as independent workers, experience with interdisciplinary collaborations, and sometimes experience working on market-focused projects. Then, I demonstrate that internships resemble ‘risky credentialism,’ in which students opt into an experience to be more competitive without full knowledge of the payoff. Finally, I show how students understand their internships as part of a broader process of assetization, in which they gain value through internship experiences. Students seek out internships to attract potential graduate school PIs or industry employers.

Real-world experience: Students often lauded internships for providing “real world experiences” that had been unavailable to them at that point in their professional training. One student says, “I loved [my internship]. It was a really great way to get a taste of engineering and...get more real-world experience with [materials] processing.” Another student says, “An internship is like the real world. It's not a grade. You're doing the science that you want to be doing.”

Student scientists frame their internships as providing “real world experiences” in relation to other professional experiences that were common for students to have. All the student scientists that I interviewed, regardless of where they had completed their undergraduate program, had volunteered in the labs of faculty scientists during their undergraduate tenure. Student scientists considered this type of lab experience to be more

important than internships for getting into graduate school. However, students described these volunteer lab experiences as tedious or boring compared to their internship experiences. For instance, one student scientist volunteered in the lab of a faculty with whom he had taken an intro course. The student describes working “for nine hours at a time” producing data for the thesis of a graduate student in the lab. Another student said her undergraduate lab work “[felt] insignificant...I got to do really small-scale reactions. Like, really small.” A third student described his undergraduate lab experiences as “slow...I spent a lot of time surfing the web [working in the lab]” he says, laughing.

In contrast to these boring lab experiences, student scientists described their internships as challenging and stimulating real world experience. When I probed, asking what they meant by real world experience, students generally described one of three experiences. First, students described internships as providing a window into science as a form of work rather than just a field of study. For students, this meant doing “more technical” science and having more responsibility over the science they were doing. For instance, one student says:

“[In undergraduate programs] you don't get hands-on experience...They try to give you labs [through classes] ... [but] someone's watching you perform the experiment, telling you, ‘Oh, you should do this, or you should do that.’ As an intern, you are given guidelines, but you're more on your own and you're learning actual lab etiquette, things that you should do. I learned more of my lab etiquette...all my basics, and even some of the more advanced stuff, through my internship.”

Another student described “real-world experience” as “experimental experience... Sometimes stuff doesn’t work. A lot of [research]... is troubleshooting. You need to have that skill.” In her undergraduate program, “the problem was laid out before me,” she says, “the way to obtain the goal was always put right in my hands.” She gained experience with experimenting and troubleshooting through her internships.

The second type of real-world experience that students gained through their internships was exposure to doing commercial science. Often, internships are situated in market contexts, and the work that interns do was driven by market goals or problems. For instance, one student interned with a rubber manufacturing company, through which he gained experience doing, “much larger reactions [than he’d ever had before], because they get huge batches [of chemical compounds] to study.” Company representatives would pose “real world material problems” to interns, like, ““We need this kind of thing,’ or ‘we are going to make these kinds of chemicals or make these kinds of polymers... We’d immediately start [testing batches] with the compounds,” he says, “testing the property of the [compound] that would eventually be used ...we were [figuring out] how to make [the product] better.”

Other student scientists had similar experiences, in which their internship had them applying their budding expertise to market problems for the first time. For instance, one student worked on a project developing radiation-resistant polymers that will one day be important for the commercial space industry. Another student worked for a defense company on a team developing stronger bulletproof vest material. Several students had worked for food companies on projects focused on developing cheap, sustainable food packaging. While most internships were housed in industry, I had the opportunity to

observe an academic internship for over a year. The academic interns also focused explicitly on market problems, conducting patent searches and consumer research in an effort to develop new prosthetics adhesion. Through internships, undergraduate student scientists gain experience applying their burgeoning expertise to market problems. One student scientist told me her internship taught her to think about “the obvious and attainable applications” of the knowledge she produces. The only students in my sample that did not work on market problems through their internships had held their positions at national labs.

Finally, students described their internships as “real world experience” because it gave them firsthand experiences with interdisciplinary collaboration. One student scientist, a chemist, said:

[Through my internship], I ended up talking to a lot of people in biology, like toxicologists, and I actually learned how to pipette there before I [started graduate school] only because they needed an extra hand. I said, ‘Sure! I have an afternoon, so I’ll sit here,’ and so I learned a whole bunch of new lab skills that I never, ever would’ve touched on as a Chem undergrad... [at my internship] I learned how to [pipette] and I learned a new understanding of what biologists in general, more than I ever could at a university.

Students’ early professional experiences often take place in rigid disciplinary contexts, like classes or a faculty lab. In contrast, internships were often interdisciplinary. One student says: “[I liked that] I was actually exposed to different people from different backgrounds. We were all working together...we’d think about certain products [being

made at the company] and talk about how to improve those products.” Another student says: “I liked that, in internships you often [work] with a group. I could learn how to...work with others to problem solve, not necessarily my boss, but other interns. We used our different backgrounds to be like, ‘Okay, let's see if this works.’”

Risky credentialism: While students lauded their internships for providing real world experience, not all internships provide the same professional opportunities. As in other fields (Frenette 2013), STEM internships were often vague, with the style and substance of internships spanning from doing applied research to doing clerical work or getting coffee for permanent employees. Some students got real experience contributing to a project in both a technical and intellectual level. For instance, Amber says:

“[Internships] gives you a lot of flexibility. [During my internship] I worked primarily in one lab. [The company needed help in a different lab] but couldn't hire another person. So they asked me, ‘If you can finish your work early, do you wanna go do some work with them, because they need another set of hands,’ and there's some things that I can start the reaction and then go and run over to the other thing...I was able to do that...I was able to jump in and have a continuous line of work, so I've had three different experiences in different groups in that company, and two of them were in central research, and one of them was in a product-facing part of the company.”

At Amber's position, she gained experience not just with the lab group with which she was hired to work, but two other groups as well. She also gained experience with basic

and applied research. The flexibility of Amber's position is a hallmark of precarious jobs (Vallas 2012). Amber describes swiftly moving back and forth between lab groups to fill various labor shortages. As she tells it, her work was in lieu of hiring another permanent employee. The flexibility of the work and its replacing of more secure jobs are two characteristics of precarious labor (Kalleberg 2018; Frenette 2013; Millar 2017).

Most students did not describe having as much hands-on research experience as Amber. Some described their internships as bad or mindless. For instance, Ian interned at a company that was undergoing rapid growth while he worked there. "[The company] didn't have enough real employees to do everything. I was put in charge of projects, but I would mainly run meetings. I had a very project-management type of job." Another student was assigned to a team that tested batches of tire rubber all day. And Raul, who was tasked with working on quality control for a military contracting company, described his internship as "an endless cycle of...menial tasks":

The problems are very well defined, right? They have this thing they want you to accomplish...When you do it, it's done. Move onto the next. It was very simple work. Very nicely laid out. There's no thinking involved. At least in my experience, there was no thinking involved. I would do it, it would be done, move onto the next thing.

A few students reveal that they received no research experience through their internships at all. Together, the above experiences resemble 'risky credentialism'; students engage in positions to gain a competitive edge, but the payoff may be very little beyond a line on their CV. However, it was more common for students with bad internship experiences to

describe doing mindless tasks or other kind of labor through which they felt exploited.

Thus, while everyone tries to line up an internship, they are not all guaranteed to pay off in the same way.

Competitive assets: Student scientists understand their internship experiences as part of a process in which they construct themselves as assets for future employers. Internships provide students an opportunity to gain valuable experiences that will set them apart from their competitors. For instance, one student said her undergraduate internship was “really valuable” because it gave her “experience in multiple lab settings before [going] to graduate school... [which can] make you a more competitive applicant.” Another student in the process of applying for graduate level internships sought these positions because of the added skills they provide. She says:

I've talked to a few people that do what I want to do. They know a computer language or some other skill...those other things that make you stand out. My PI is always bugging me to do more [of those things]. Everybody has a dissertation, so you have to do something else too.

Universities have increasingly pushed a human capital approach to higher education (Brown 2015). Both examples emphasize the human capital approach, increasing things that could be valuable, making her competitive “Everybody has a dissertation, so you have to do something else too.”

Another student, Chad, was clear that his internship made him an asset to potential employers. Chad said:

“Students who apply [to graduate school] without internship experience are forced to say their only hands-on experience is [lab experiences they found through] their classes, which everybody has. They're forced to say, ‘I have interest and passions for these subjects,’ which everybody says. People can lie. When you have internship experience, you can say, ‘You don't need to train me on the basics of handling a pipette or measuring with a graduated cylinder.’ All the basic stuff, that's covered. I'm ready to hit the ground running...”

Chad describes internships as signaling passion for an area of research, which may set them apart from other people competing for the same position. Chad also describes an internship as a signal that he knows a certain set of useful skills, like pipetting. Here, we see allusions to the human capital frame that is so prevalent among neoliberalism (Brown 2015). I ask why it's important to demonstrate an ability to “hit the ground running.”

Chad replies:

“It takes a while to train somebody, and a faculty...don't want to waste time. When you say, ‘I've already got experience in this area. I've already got an interest in this area. That's what you're doing. When you hand me something, I can run with it.’ For a graduate school advisor, that's money. They love it.”

Academic science has an education mission, but Chad's perception is that faculty “don't want to waste time” training new students. Students often shared this sentiment. For instance, Carol, another graduate student, told me that her, “PI is busy...he can't be

teaching you how to do things.” Faculty face increasing pressures to produce and growing oversight in their careers (Shore and Wright 2000; Espeland and Saunders 2016). Students understand their PIs as busy, and so demonstrating they already have necessary skills means saved time and money in the lab.

Graduate students also considered graduate-level internships as added value on the job market. For instance, during a graduate-level class discussion on the job market, the professor leading class that day asked if any of the students had worked in an industry internship during graduate school. Of the thirty students, only a few raised their hands. The professor points to one of these students. “What was that [internship] experience for you?” The student thinks, then says, “It was a test run.” The professor nods. “It most certainly was,” he says. He tells the class that, in his two decades at the university, there had been a stark increase in graduate students finding work in industry after graduation. He urged student scientists interested in industry careers to find an industry internship as graduate students. He told the class that graduate-level internships would “lessen the industry learning curve” and signal to potential employers that they “know the ropes” of industrial work. This could lead to a more stable job “out the gates...[because] it’s a sad day when your first job out of your PhD is temporary because you’re still figuring things out.” The professor tells the students an internship would show potential employers a student was prepared “to transfer to industry and hit the ground running.”

This was common. For instance, one student said, “If you do want to go into industry, there’s a whole different set of expectations in lab culture and everything. You’re definitely missing out if you haven’t seen any of that if that’s where your end goal is.” Another said:

“In my department, a lot of people end up going into industry when they graduate but have zero industry experience...I think having a [graduate] internship, even if it's just for two months over the summer, just to get an experience of what industry research and industry life was actually like, would be really important to showing people, ‘hey, I actually want to do this.’”

Other students more explicitly highlighted how internships would increase their value. One student said, “[I’d like to find a graduate internship] ...so I can go into an industry with a better resume in the future.” “They really like to see that you have industry experience because if you've only had academic experience, sometimes PhD employees are expensive, and they don't want to pay that kind of money to somebody who has had no project experience.”

Students understand internships as experiences that raise their value in the job market. As I have demonstrated, faculty encourage undergraduate students to find internships to make themselves attractive to future employers. But faculty did sometimes acknowledge that internships were generally undesirable as well. During a lecture focused on the job market, the professor explains that internships would really help students show employers they were ready for work. Then, he tells the class that internships “may seem undesirable” because of their “temporary” nature. “When I was in grad school,” he says, “we wouldn’t work those jobs, because you would be considered ‘less than.’...[But] your generation, you’re used to moving around.”

DISCUSSION & CONCLUSION

I began this chapter describing how internships have both cheerleaders and critics. The cheerleaders laud internships as high-impact opportunities that will help young professionals be competitive on the job market (O'Neill 2011; Pain 2008). Critics decry internships as precarious and exploitative. In this chapter, I show that STEM internships can be both. Student scientists entering the scientific field are competing with others for valued resources, whether that be funding from an academic lab or an industry position after completing their PhD. Internships are not mandatory positions, but they are still normative. As I discussed in Chapter 2, students face an increasingly precarious job market. Thus, while internships are not necessarily mandatory in most cases, there is still a credentialing aspect to them. Students understand their internship as a legitimate way to engage in the competition of getting ahead in STEM careers. Some get internships while others do not. Those who do add to their human capital, and hopefully attract the investment of a PI or a future employer.

Just as the job market is unstable, so too are the structures of internships. I demonstrate that there is some risk for students who sought STEM internships. While most STEM internships are paid, the content of internships varies widely. Some students' internships clearly gave them value by providing them with experience as an independent researcher, as a collaborator, or even as an innovator. Other students' internships were mundane, providing them with devalued tasks. In part, credentialism is about having the credential on one's CV, and so even a bad internship might look fine on paper. On the other hand, if students are being taught to seek out experiences that will appreciate their value, bad internships are wasted time and a missed opportunity for some other

experience that could have been more valuable. Scholars have found that those who get the best internships are often privileged along race and class lines (Frenette 2015). Future research should consider how STEM internships are potentially structural barriers to STEM, despite not being a mandatory prerequisite for graduate programs.

We also know that faculty are also expected to work in ways that increase their value. Critics view this differently and accuse universities of abetting the rise in exploitative intern labor (McDermott 2013). Knowledge workers are disciplined to engage in credentialing and other experiences that appreciates their market value (Foucault 2010; Brown 2015). Internships are early experiences in a student scientist's career in which it is normative to seek out nonmandatory experiences that will appreciate their value. Faculty, postdocs, and graduate students are to some degree expected to become more valuable, and to treat themselves as assets under academic capitalism.

[1] The Department of Labor has a seven-point scale to determine if interns and students working for “for-profit” employers are entitled to minimum wages and overtime pay under the Fair Labor Standards Act <https://www.dol.gov/agencies/whd/fact-sheets/71-flsa-internships>

CHAPTER 4: INVENTING MASCULINITY: RELATIONAL PROCESSES OF GENDERED RESEARCH COMMERCIALIZATION

Academic capitalism has implications for gender equity in higher education (Ferree and Zippel 2015; Smith-Doerr and Croissant 2011; Whittington 2011).

Institutions of higher education have become increasingly businesslike, valuing knowledge privatization and for-profit strategies “that favor institutions, inventor faculty, and corporations” (Slaughter and Rhoades 2004: 29; Slaughter and Leslie 1996; Kleinman and Osley-Thomas 2014; Kleinman and Vallas 2001). In recent years, universities have promoted profits by weighing research commercialization more heavily in faculty tenure and promotion decisions (McDevitt et al. 2014; Sanberg et al. 2014). ‘Research commercialization’ refers to the conversion of knowledge produced at universities into market products, specifically patents (Maktabi 2009). Bibliometric analyses of patents highlight that commercially active scientists are more likely to be men (Colyvas et al. 2012; Ding et al. 2006; Hunt et al. 2013; Koning et al. 2020; Metcalfe and Slaughter 2008; Sugimoto et al. 2015; Whittington and Smith-Doerr 2008). Thus, weighing research commercialization more heavily in tenure and promotion favors men.

Over the years, the federal government has promoted academic commercialization as a strategy to generate economic growth (Berman 2012; Berman 2013). For instance, the 1980 Bayh-Dole Act allowed universities to patent knowledge that faculty had produced using federal funds rather than assigning those inventions to the government. The two decades following Bayh-Dole saw an 850% increase in U.S. university patenting (Owen-Smith and Powell 2003; Henderson et al. 1998). Increasingly profit-focused,

universities encouraged faculty commercialization through new infrastructure, like technology transfer offices or university-industry research centers designed to streamline research commercialization (Owen-Smith and Powell 2003). Weighing commercialization more heavily in faculty evaluations is just one example of academic capitalism driving institutional change in favor of profits. Overall, tenure has become harder for junior faculty to attain in recent years (AAUP 2018), while the overall number of tenure-track jobs is shrinking (Benderly 2004). Thus, universities are giving commercially focused faculty scientists (who are more often men) opportunities for stability while non-commercial faculty scientists face growing precarity in higher education.

Why do men scientists engage in research commercialization at higher rates than their women counterparts? Research looking at gender disparities in science shows that relational structures often play an important role in shaping gender inequalities (Fox et al. 2017). For instance, Whittington (2018) analyzes a global patenting collaboration network of men and women inventors to understand “where women ‘sit’” in the networks. While women scientists collaborate on research at higher rates than men, Whittington shows women are less likely to collaborate on projects that yield patents. When women do collaborate on commercial projects, they are more likely to collaborate with men than with women. This has implications for efforts to integrate more women into innovation spaces, as women that are included will, “bring other women (and new ideas) into the commercial context” (2018: 523). Thus, public policy promoting gender equity in science should address this gender gap in research commercialization.

Most of our knowledge about gendered patterns of research commercialization comes from bibliometric analyses of patent counts and patent citations. Bibliometric studies provide an important field-level view of gendered research commercialization over time. But bibliometric studies are also limited in their capacity to explain the organizational and interactional processes that generate field-level outcomes or identify the many material benefits that commercially successful faculty gain. To identify the organizational and interactional antecedents and the structural outcomes of this gender patenting gap requires qualitative analysis. Building on five years of ethnographic fieldwork and 60 interviews inside two market-adjacent academic science organizations, I investigate: (1) how gender shapes who is included and excluded from the commercial contexts of academic science, and (2) the material repercussions of exclusion.

I find that gendered team and organizational processes around recruitment, division of labor, and visibility privileged men's integration into innovation contexts while simultaneously excluding women. I argue that *inventor masculinity* – a form of hegemonic masculine domination performed in innovation contexts – contributes to these dynamics as well. Men blend hegemonic physical science masculinity and market competition to navigate inclusion in commercial contexts. Through this process, feminine-typed research practices, expertise, and experiences are devalued. Whereas competition is central to commercially focused knowledge production, I find that engaging in competition through commercial research is central to men's performance of inventor masculinity. This performance has epistemic effects. Competition becomes central to how research problems are organized and executed, often to the detriment of more 'feminine' research strategies that center on inclusivity and collaboration.

I also find that processes that facilitate women's exclusion from innovation contexts in turn enable men faculty's social closure around valued resources (Tomaskovic-Devey and Avent-Holt 2019). I specifically focus on funding, prestige, students (as laboratory labor), and space. My findings suggest that university administrators' growing valuation of research commercialization in tenure and promotion decisions will exacerbate gender inequities in academic science. This commercial science divide is yet another example of a gendered 'Matthew Effect' in science (Smith-Doerr 2011; Zuckerman 2011; Rossiter 1993) in which male privilege begets more privilege. In academic science, the growing valuation of research commercialization creates unique opportunities for men scientists to find security in a field of growing instability.

GENDERED ORGANIZATIONS, HEGEMONIC MASCULINITY, AND THE PHYSICAL SCIENCES

This paper draws on gendered organizations theory developed by Acker (1990; Britton and Logan 2008; Mickey 2019; Smith-Doerr et al. 2019), and hegemonic masculinity theory developed by Connell (1987; Connell 1995; Duncanson 2015; Messerschmidt 2017; Schwalbe 2014) to show how gender facilitates inclusion and exclusion from innovation contexts. Gendered organizations theory highlights how organizational structures privilege men in the workplace, while hegemonic masculinity theory focuses on how men access their privilege through asserting dominance in socially meaningful ways. Together, these theories provide a framework to critically analyze the organization- and interaction-level processes that shape women's exclusion from

innovation contexts. Following my outline of these two theories, I delineate the ways that ‘inventor masculinity’ contributes to scholarship on gender inequality in the physical sciences.

Gendered Organizations Theory

Scholars of gendered organizations investigate how workplaces enact seemingly gender-neutral rules, policies, and practices that perpetuate patriarchy (Acker 1990). Organizational structures around job descriptions or evaluative practices often favor masculine behaviors and practices, which lead to more opportunities for men. Conversely, women face harsher criticisms than men in workplace evaluation (Martin 2003; Rivera 2017; Rivera and Tilcsik 2017). Within gendered organizations theory, the ‘ideal worker’ is presumably a man, “rational, a strong leader, committed to work and unencumbered by familial or other responsibilities” (Brumley 2014: 801; Collinson and Hearn 1996). Gendered images of the ‘ideal worker’ as male are culturally reproduced, reaffirming “masculine attributes for success and ascribe women’s lack of advancement to the absence of these attributes” (Brumley 2014: 801).

Within gendered organizations, certain jobs become gender-typed masculine or feminine, in which gender stereotypes are attached to jobs (Doering and Thebaud 2017). For instance, organizations often value a masculine ‘ethic of rationality’ for successful managers (Acker 1990). In these contexts, women are relegated to devalued, feminine-typed work (Blair-Loy 2001; Cohen and Huffman 2003; Ridgeway 2011), which often hinders their career advancement (Roos and Gatta 2009). The gendering of jobs shapes

hiring decisions, pay rates, and performance evaluations, processes that reproduce gender labor market inequalities (England 2010; Ridgeway 2011; Rudman and Glick 2008; Smith-Doerr et al. 2019).

Within organizations, men and women experience different levels of visibility. Sometimes, women in masculine spaces face tokenization, which can lead to both material benefits and interactional constraints (Kanter 1977). For instance, women in masculine spaces may experience discrimination from men colleagues who socially differentiate themselves from ‘the feminine,’ “[exaggerating] *dominant cultural boundaries*, leaving those in the minority isolated” (Wingfield 2013: 8, italics in original). Feminist scholars have used intersectionality to understand myriad ways gender, race, ethnicity, and other parts of one’s identity shape our experiences (Collins 2015; Misra et al. 2021), including in knowledge work (Alegria 2020; Rodriguez et al. 2016). A key limitation of this chapter is that it investigates gendered organizations without an intersectional analysis with race. This analysis of masculine privilege in commercial science should be viewed as a first step in a series of needed studies.

Social network dynamics are important processes in the reproduction of gendered organizations. Often, women have described their exclusion from networks as a key barrier to career advancement (Cech and Blair-Loy 2010; Lutter 2015; McIlwee and Robinson 1992; Smith-Doerr 2004). Seemingly gender-neutral organizational processes reproduce gendered patterns of relationships in organizations, which in turn legitimates the unequal distributions of resources by gender (Blair-Loy 2001; Williams et al 2012). Feminist scholars have found that men are accepted into important professional networks more easily than women, highlighting the continued, “existence of an old boys’ network

[that] excludes women and curtails their success” (Davies-Netzley 1998: 347). Gender institutions shape gender discourses (Martin 2013), which in turn gives meaning and legitimacy to inequality across gendered network structures.

Hegemonic Masculinity Theory

‘Hegemonic masculinity’ refers to dominant masculinities “that *legitimate* an unequal *relationship* between men and women, masculinity and femininity, and among masculinities” (Messerschmidt 2017: 120, italics in original). Relationality and legitimacy are important to hegemonic masculinity theory; just as masculinity only exists in relation to femininity, hegemonic masculinity can only exist in relation to subordinated masculinities and femininities (Carrigan et al. 1985; Collinson and Hearn 1996; Pascoe and Bridges 2017). Hegemonic masculinity unfolds differently across contexts, yet it always “occupies the hegemonic position in a given pattern of gender relations, a position always contestable” (Connell 2017: 139).

I find that men navigate inclusion into innovation contexts by engaging in research and market competition. Masculinity scholars argue that men assert dominance through ‘manhood acts,’ “aimed at claiming privilege [and] eliciting difference” (Schrock and Schwalbe 2009: 281). Manhood acts take on different characteristics in different social contexts. Men perform manhood acts to construct differences between men and women and to subordinate other men in their efforts to amass power and wield privilege. This subordination often happens through socially meaningful competition (Schwalbe 2014; Duncanson 2015). Historically, competition has been important to science (Gaston

1971; Mitroff 1974). Competition has only become more central as science has grown closer to the market (Hackett 1990; Johnson 2017; Patel and Ward 2011). Conversely, competition in science has been found to undermine women's success (Niederle and Vesterlund 2011; Schram et al. 2019). In scientific contexts, competition may also undermine women's collaboration and creativity (Baer et al. 2013).

Inventor Masculinity in Innovation Contexts

I argue that men navigate their inclusion into innovation contexts through performing 'inventor masculinity.' I develop this concept on a foundation of feminist scholarship analyzing men's relationship with the physical sciences. The physical sciences and engineering have notoriously masculine cultures (Ecklund et al. 2012; Margolis and Fisher 2002; Ridgeway 2012; Smith-Doerr et al 2019), and many young men pursue physical science careers to cultivate professional and masculine identities (Oldenziel 1999; Traweek 1999). Many skills considered necessary for success in the physical sciences, like "mastering" expertise, using tools, tinkering (Cockburn 1985; Oldenziel 1999; Faulkner 2007; Wajcman 1991) or separating social and technical competencies (Cech 2014), are gender-typed masculine.

'Inventor masculinity' describes how hegemonic physical science masculinity intersects with market forces to create unique processes of domination in innovation contexts. Market competition becomes intertwined with traditional masculine skills like the separation of the social and technical, and embedded in the epistemic process of commercial knowledge production. Below, I argue that competition is central to the

epistemic culture of innovation spaces (Knorr-Cetina 1999), a central way that innovative scientists interact with knowledge (and other researchers) in the same institutional space.

METHODS AND DATA

This study builds on a five-year ethnography of two market-focused academic science organizations. Both organizations are rooted in the physical sciences at the same U.S. public research university, and both are interdisciplinary, drawing faculty and students from material sciences, chemical engineering, mechanical engineering, physics, food science, and biology. I conducted this fieldwork to investigate how academic capitalism is shaping the work and training of student scientists. While my larger project is an organizational comparison, there was no significant variation across my sites in relation to this article.

I observed my first site, the Biomaterials Research Center (BRC), from August 2014 until June 2019. Two years before I began my fieldwork, Dr. Edwards and Dr. Arnold, BRC's co-PIs,[1] had collaborated on a commercially successful bioinspired adhesive. When I met Dr. Edwards and Dr. Arnold, they were establishing BRC to pursue new research opportunities that had arisen from their commercial success. A social science faculty introduced me to Dr. Edwards and Dr. Arnold. I began observing BRC early in its development, before the organization had any funding, and before they hired a paid administrator. I observed my second site, the Soft Materials Research Traineeship (SMRT) from August 2015 until December 2019. SMRT is a federally funded graduate traineeship program that trains student scientists on how to collaborate with academic,

industry, and government audiences. It focuses on students working at the nexus of soft materials in the life sciences, an emerging subfield and market. For five years, I was funded by SMRT to conduct a ‘science of science’ study of the program. I began observing SMRT before any students had been admitted to the program.

The physical sciences are often hostile spaces for women. However, the faculty at both sites visibly supported women’s equity in their disciplines. One respondent had received a grant through the National Science Foundation (NSF) ADVANCE Program on campus, which promotes structural change for faculty gender equity in STEM. A SMRT PI was active on university equity committees. A survey of many of my respondents’ laboratory websites reveals statements of commitment to diversity and inclusion and many of the faculty affiliated with my field site expressed commitment to this endeavor. This point also provides important context for my findings. The barriers I observe are arising in contexts where women’s equity is a stated goal.

My work builds on classic laboratory studies that investigate how social and structural processes shape knowledge production (Latour and Woolgar 1979; Traweek 1989; Knorr-Cetina 1999; Kleinman 2003). I conducted some observations at the bench, but I conducted most of my fieldwork during meetings. Meetings are key sites of organizational decision making (Sanders and Thedvall 2017). In science, meetings are contexts in which knowledge production is organized, negotiated, or contested (Vertesi 2014). I observed faculty meetings, student meetings, graduate classes, seminars and other formal BRC and SMRT meetings. I travelled with my respondents to professional conferences. I also attended informal gatherings at backyard barbeques and the university pub. Through my field sites, I gained access to broad university organizations and

systems that facilitate university-industry relations (UIRs). Through my sites, I also gained access to the weekly meetings of two commercially focused labs, each for a year.

My respondents were aware of my presence and my study. In both sites, I often restated myself as a social science observer when new people joined the organizations. Faculty often joked about my presence; for instance, that I was like Jane Goodall and they were like her chimpanzees. My positionality as a straight, white cis-gender man undoubtedly shaped my opportunities for observation and information in these traditionally white, male-dominated spaces. I arrived on my first day of fieldwork wearing jeans, sneakers, and a button-up shirt, and was indistinguishable from the other three graduate students in attendance. All three were white men, like me, of similar age, dressed similarly. My positionality helped me access the informal, masculinized contexts of innovation spaces. My positionality may have also limited similar access with women students or students of color.

In formal meetings and classes, I took field notes on my laptop, as it was the norm for each person to have their personal computers out in these spaces. This note-taking would give me a skeletal frame of events and conversations that I would fill in later that evening. In less formal contexts, I relied on classic tricks of recording field notes in stairwells or bathroom stalls and fleshing out details later. Overall, I conducted 179 separate observations in the field between my two sites. The durations of observations varied. Most were formal classes or meetings lasting 60 to 90 minutes each. Others were day long affairs at conferences, or the odd weekend afternoon cookout hosted by a PI. My fieldwork is supplemented with 60 semi-structured interviews with academic faculty, students, and administrative staff. Table 4.1 categorizes my respondents by field site and

structural position. Table 4.2 categorizes my respondents by gender. My interview script had two questions about how my respondent's gender facilitates or hinders their relationships, but otherwise gendered experiences were not my primary focus. However, interviewees often brought up gendered experiences without prompt. In these moments, I would pause to further explore these gendered experiences.

I coded these data using NVivo, a qualitative analysis software. My first round of coding focuses on identifying the relational and discursive social structures (Messerschmidt 2017: 117-119) that shaped the gender patenting gap. From there, I inductively developed my argument, zigzagging between feminist scholarship on scientific work and these data.

[Table 4.1 about here]

[Table 4.2 about here]

HOW GENDER FACILITATES INCLUSION AND EXCLUSION IN INNOVATION CONTEXTS

In this section, I analyze how gender shapes who is included and excluded from innovation contexts. First, I show how recruitment, division of labor, and visibility processes on teams and organizations facilitate men's integration into innovation contexts while simultaneously creating barriers for women. Then, I show how men perform inventor masculinity to navigate inclusion into innovation contexts, specifically by centering competition in knowledge production.

Teams and Organizations

I had access to three innovation teams during my fieldwork. Each team was rooted in organizations (labs or research centers) with near-even gender representation, yet each team was composed almost exclusively of men. For instance, one of these teams sought to design new wig adhesion technology that could adhere to a user's scalp while also being easily removable. This wig adhesion research was the first project that BRC faculty undertook as a "research center," before they had secured any external funding. Thus, all preliminary work was unfunded, and developed with potential funders in mind. BRC faculty recruited six "promising undergraduates" from the labs of BRC-affiliated faculty to work as interns on the project in exchange for course credit. Of these interns, there were five men and one woman. These recruitment patterns reflect findings that show faculty biases tend to favor men students over their women counterparts (Moss-Racusin et al. 2012).

The intern's work on the team reflected widespread gendered expectations of work within science. The five men interns were assigned to the wig adhesion project. These interns conducted literature and patent reviews, produced preliminary data, and even contributed intellectual ideas as to how this new technology could be constructed. The woman intern worked on BRC's educational outreach project alongside the BRC administrator, the only other women actively working on the team. On the educational outreach project, the woman intern compiled kits of dead ladybugs, helicopter seeds, and

other found items from nature that could be used to teach scientific principles to kids. She and the BRC administrator distributed these kits to local schools and museums.

Both the wig adhesion and the educational outreach projects were important to BRC's appeal to funders. The faculty needed to present preliminary data and situate their work in the market in their appeal to industry funders. The men interns' work on the wig adhesion project allowed BRC faculty to assemble the necessary pieces for this initial appeal despite a lack of funding. The faculty saw the educational outreach program as important to BRC's funding strategy as well. During one meeting, a PI says: "I strongly feel [the educational program] will be our key to getting money for the long term," because funding K-12 education "appeals to the state, and private companies will want to back it." As they review the kits compiled by the woman intern, another says, "this will be a cool, distinct feature of [BRC]. It'll set us apart from other centers."

The commercial experiences of the men interns make them more likely to innovate in the future (Azouley et al. 2017). For instance, one BRC PI taught the men interns how to legally protect their ideas. Interns had been instructed to draw designs for their wig adhesion technology. After each intern presented, the PI instructed interns to describe how their designs could be "logically constructed." Then, "take the photo with a time stamp for IP issues," he says, before warning them against publicly presenting on their ideas because, "the new rule [in knowledge production] is...first to file, not first to ideas." Once they have publicly presented an idea, "all IP rights go out the window." Gendered expectations around scientific work shapes experiences that make these men interns likely to pursue innovation in the future. Their woman counterparts were not included in these opportunities.

When BRC faculty finally made their appeals to funders, the men intern's work was more visible than the work done by the woman intern. During BRC's presentation to potential funders, Dr. Edwards described the interns among the many valuable outputs produced by the center. He told them these students "will be an asset" to companies because of their early experiences developing new IP. These experiences "gives [the interns] real world experiences" that they could, "bring...into companies and apply in new ways." The PI briefly mentioned the educational outreach program but did not highlight the work of the woman intern as he had with the men.

The above case highlights how recruitment processes create barriers to women's integration into innovation contexts. The recruitment of 'promising undergraduates' from faculty labs yielded five men and one woman. Faculty recruit men students onto the wig adhesion project based on interest, which fits into gendered assumptions about scientific work. Through these opportunities, men interns gained valuable entrepreneurial experience and an entrée into innovation networks. The woman intern works on a project that faculty consider key to BRC's financial survival, but the PIs do not celebrate her work as they do her men counterparts. This woman intern was also tracked into clearly feminine-typed work. Feminist scholarship shows that work with children and education are women dominant sectors, while receiving less pay compared to men dominated sectors requiring comparable credentials and skills (Roos and Gatta 1996; England 2010; Reskin and Beilby 2005; Folbre 2021).

Gendered visibility processes shape barriers to women's integration into innovation contexts in other ways. For instance, Dr. Erica Kelly, an assistant professor in the physical sciences, felt she had been given many opportunities because of her gender.

“There are precious few women serving [in the physical sciences]. We have a very-low percentage,” she says. She describes her recent experience with a market-focused research center she had recently joined. The PI had emailed her “out of the blue,” telling her that her research aligned with the goals of the center:

“My gut feeling is that they needed some women,” she says. “I don’t know if that’s true, but that’s my gut feeling. I’d only been at [the university] for four months. There was no reason for him to know who I was. I had nothing to offer. I didn’t even have lab space. I was barely getting through my teaching assignment. I didn’t know [anything about their research]. I don’t know any people. I am not bringing anything to the table, but he goes, ‘I think you’d be great.’ I’m not a materials person. I’m not a physics person, [but] I am the only woman in [my department], so that’s my gut feeling.”

Dr. Kelly was featured prominently in the center and given opportunities to present potential funders on behalf of the organization. Through her involvement with the center, she met a biologist, and “[the center] spun out enough money” for the two of them to collaborate. But she was never asked to be a part of high-profile, multimillion-dollar grants funded by big companies. Those projects primarily consisted of men. Reflecting, she said: “The companies we’re talking to are not interested in what I do. I’m not developing new materials. I am not developing cool new ways to test them... They don’t care about [my work]. That’s another reason I suspect that it was maybe a gender opportunity, asking me to join.” Dr. Kelly’s experience mirrors broader trends of women’s tokenization in innovation contexts, appearing as representatives while their

expertise and experiences are devalued. These visibility processes create interactional barriers to women's inclusion into innovation contexts.

Inventor Masculinity

Men scientists perform 'inventor masculinity' to navigate inclusion in innovation contexts, a process that simultaneously devalues 'feminine' approaches to research. Sometimes this occurred explicitly, as men inventors evoked differences between masculinity and femininity in innovation spaces. For instance, the wig adhesion team often bought products that could inform their research. In one case, they bought a handful of femme wigs to use with their technology. During one team meeting, interns took turns donning the wigs while talking in effeminate voices while their peers laughed. In another case, they bought a strapless bra with adhesive strips on the side:

Ben, a graduate student, brought the bra to the research team meeting. "I feel weird having this in my desk drawer," he says with a smile as he holds the bra awkwardly. He is stiff, uncomfortable. He sticks the adhesive to his arm. "I guess most women aren't as hairy as my arm," he says as the adhesive fails to take hold. He tells us he had tested how many times he could use the adhesive strips before they would fail. As he describes his experiment, Ben is conscious of the bra. He looks at it with a smile as he talks. The interns grin. He finally tosses the bra onto the table and the room fills with laughter. The two PIs tease Ben about the bra between technical questions about his experiment. Colleen, the BRC

administrator and only woman present, laughs too, but says nothing. (Fieldnote excerpt)

In performing hegemonic masculinity, men create a hierarchy between the masculine and feminine, often through devaluing feminine practices, technologies, or experiences.

However, men often drew distinctions between the masculine and feminine in more subtle ways. Consider another embodied discussion of materials at BRC:

...the BRC faculty moved to discuss their long-term goal: to scale up from wig adhesion to prosthetics adhesion. Their primary material challenge is designing an adhesive pad that will fit the different contours and tensions of people's bodies. Dr. Edwards presents a classification system he had developed that accounted for different levels of curvature of the body. He draws a hollow silhouette of a person on the board and talks about the different curvatures of the human body as he points to the head, the calf, or the armpit. He describes how skin is stiffer on the head than on the back or the side, which also affects the adhesion of their material. Developing a system to classify the different curves and tensions should be their next step. Dr. Arnold agrees: "Our goal [should be] mastering adhesion to compliant, curved surfaces," he says. Dr. Duval, a biologist and the only woman faculty present, raises her hand: "Remember, these compliant, curved surfaces move a lot." There are some chuckles from the team. (Fieldnote excerpt)

This example of a subtler reference to breasts than the bra example also highlights the separation of the social and technical, a prime narrative of hegemonic physical science masculinity (Haraway 1985; Cech 2014; Milam and Nye 2015). As Dr. Duval highlights,

BRC faculty portrayed user's bodies devoid of social context. Students often emulated this masculine performance in conceptualizing their work vis-à-vis society. For instance, during one meeting the team discussed posts from an online support group for people suffering from hair loss:

The team focused on one post made by a mother, who felt her balding had negatively impacted her relationship with her daughter. On a recent vacation, the mother and daughter rode a roller coaster together. As they buckled into the ride, the mother removed her wig and secured it in her purse. During the ride, an automated camera had taken a picture of the riders. The photo of her without her hair "had traumatized [her] daughter." She never lets her family see her without her wig. She was devastated by her daughter's reaction. The intern that found the post says he thought it was important to discuss because it gave the team clear testable parameters: Could their wig adhesive sustain a ride on a rollercoaster? (Fieldnote excerpt)

Again, inventor masculinity builds on hegemonic physical science masculinity. As the cases above highlight, men students learn this style of masculinity from men faculty, and perform it as a strategy to navigate acceptance in these spaces.

Inventor masculinity exists at the intersection of hegemonic physical science masculinity and the market. In innovation contexts, men are privileged by asserting dominance through engaging in market competition. For instance, Dr. Edwards was presenting to industry funders on behalf of BRC. He describes how bioinspiration, a heuristic research approach that uses principles from nature to solve material problems

(Fisch 2017), has been central to BRC's program. Dr. Edwards then dismisses other teams branding their work as 'bioinspired' as 'biomimicry.' "They say they are bioinspired, but they just mimic things they find in nature," he says. "Biomimicry is seeing feathers on birds, putting feathers on humans, and expecting [them to] fly...Bioinspiration is [BRC's] business: it's not about the feathers, but the whole macrosystem of birds that allowed for them to fly, taking the core principles from that, and figuring out how to use those principles in designing new concepts and products." Performances of masculine competition arose through undercutting competitor's work as a funding strategy.

Performances of masculine competition also arose around market prestige. This assertion of dominance through market competition was also clear in situations where market success arose. For instance, one faculty shared his anxiety about being 'one-upped' by a competitor. Years prior, he had helped develop a bioinspired adhesive that was a market success. Now, another team at an elite university research was making similar technology. The team had made a video featuring graduate students climbing walls using their adhesive. The video went viral and was covered by high-profile media outlets. I ask if he saw the team as competition. "Absolutely," he says. He then boasts, "their product will never sell," citing its complicated design and narrow application. On the other hand, his adhesive was simple, with many uses and applications.

Men perform hegemonic masculinity in socially meaningful ways to access male privilege. In innovation contexts, commercial success is central to this assertion of dominance. Above, I described a BRC faculty teaching interns how to legally protect their ideas. The faculty had warned them against presenting their ideas because, "the new

rule [in knowledge production] is...first to file, not first to ideas;” once an idea has been publicly presented, “all IP rights go out the window.” In another example, in a group of graduate students talking about their work at the university pub, a senior male student tells us we cannot legally discuss the project with anyone outside the university because of the nondisclosure agreement written into our contracts. Protecting ideas from future competitors (real or imagined) is an important component of performing inventor masculinity.

Subordinating the work of others (rather than viewing it cooperatively or as ancillary) is central to inventor masculinity. At its most extreme, this masculine performance of market competition becomes part of the epistemic process of commercial knowledge production. For instance, the wig adhesion team of interns spent weeks searching Google Patents to find work similar to the wig adhesion technology they were designing. Led by an advanced man graduate student, the interns learned to identify design weaknesses of competing technologies that could be exploited. It was through identifying and deconstructing the work of competitors that the wig adhesion team clarified its research questions and designed experiments that would appeal to funders.

Through inventor masculinity, the masculine and feminine are divided and ranked. Men scientists “other” feminine-typed experiences, likely hindering women’s integration into commercial contexts. As a type of hegemonic masculinity, inventor masculinity is about asserting dominance through market competition over funding or prestige. Competition is a central dynamic between innovation teams, and a core component of the epistemic process of commercial knowledge production. My data suggest that student scientists learn how to perform inventor masculinity in education spaces, thus normalizing this

behavior across generations. Inventor masculinity may directly hinder women's success in innovation contexts, as competitive contexts can undermine women's collaboration and creativity (Baer et al. 2013).

RESOURCES EMBEDDED IN INNOVATION CONTEXTS

In the last section I discussed the organizational and interactional processes that bar women's integration into innovation contexts. Here, I explore how commercially successful academic faculty benefit materially from their involvement in these networks. I review four resources that commercial scientists gain access to through research commercialization: funding, prestige, students, and space.

Funding

Commercially successful academic scientists have access to large reserves of funding unavailable to their noncommercial colleagues. The federal government provides large portions of that funding. Today, the federal government contributes less to total academic research and development (R&D) than it once did, and much of what it still funds is earmarked for innovation. Of my respondents, one was funded through the NSF I-Corps program, which helps entrepreneurial researchers quickly translate "promising ideas from the laboratory bench to widespread implementation." Another had received support from the National Institutes of Health's Small Business Education and Entrepreneurial Development Program, which helps academic scientists develop

biomedical innovations by establishing a network of, “universities...businesses, trade associations and societies, angel investors, venture capitalists, and strategic partners” to support academic product development efforts” (<http://grants.nih.gov>).

As the U.S. government has decreased its total contribution to R&D, academic scientists have turned to industry to make up the difference. Driven by profits, companies often fund academic research with clear financial payoffs. Sometimes, companies fund groundbreaking technological developments; for instance, one faculty was funded by a Fortune 500 company and a private foundation to develop wearable electronics. However, most of the industry-funded academic research I witnessed sought to improve preexisting industry products or techniques. For instance, one faculty was funded by a multinational chemical company to find a more sustainable way to develop chemicals already being manufactured. Entrepreneurial universities foster ties with companies to facilitate funding for commercial-focused academic faculty, contributing to the university’s for-profit goals.

Research shows that men scientists commercialize research at higher rates than women (Whittington and Smith-Doerr 2005; 2008). Thus, these seemingly gender-neutral organizational practices for funding allocation reinforce unequal resource distribution patterns that favor men, thus facilitating men’s social closure around funding opportunities.

Prestige

Commercially successful academic scientists often gain prestige, or ascribed status in the social hierarchy (Burris 2004), through their success. For instance, the BRC co-PIs were celebrities at their university for their bioinspired adhesive. They were featured in university magazines, television advertisements, and other promotional materials. University YouTube videos spotlighting their work have hundreds of thousands of views. They delivered distinguished faculty lectures and TEDx Talks on innovation and success. Media outlets like *The Discovery Channel* and *Animal Planet* have featured their work. A professional society gave one of the PIs a career achievement award in part for his work on the adhesive.

During our interview, I asked Dr. Arnold about a plaque hanging on his wall. It was from a distinguished faculty lecture he had given on his commercial work. “[The university] really values industrial work with companies, probably because they get to then go back to [the university board of trustees] and justify their existence, right?” he says, laughing, “I get it.” But then he says the prestige that faculty get is fleeting. “This field we’re in, we constantly have to reprove ourselves. What you did yesterday doesn’t matter that much, unless you win a Nobel prize...none of that stuff really matters.” However, decades of scholarship show that prestige does matter. Privilege begets privilege (Zuckerman 2011). The reproduction of gendered innovation patterns thus acts as a mechanism of social closure, cutting women scientists off from the same opportunities for prestige as their men colleagues.

I also found women scientists' commercial success may not receive the same acclaim as their men colleagues for commercial success. One faculty member had won a prestigious award for a groundbreaking innovation her lab had a hand in producing. "I was an assistant professor, and a colleague who was a formal mentor of mine sent an email to the department saying, 'Hey, this is really cool. Our new, young colleague is on this exciting list.' I got crickets," she says. Despite the prestige of the award, university administrators and her chair "gave [her] nothing." She then describes getting praise she had hoped for a few years later, when she won a prestigious academic award. This recognition gap warrants further research (Misra et al. 2018).

Students

As students perform much of the benchwork in academic science, they are an important resource to academic faculty (Weinberg et al. 2014; Slaughter et al. 2002). Commercially successful academic scientists may have access to more students, and more internal funding. The external funding or prestige derived from commercial success gives faculty the means to fund more students, and also a brand that draws prospective students to the lab. I observed the weekly meetings of two labs, each for a year. Both labs were led by men. Lab A had a reputation for producing groundbreaking technology, while Lab B worked to improve long-standing industry research techniques. There was excitement around Lab A, as the PI received media attention for his inventions. The research was exciting, and the large lab group created a fun culture. During lab placement, new students often ranked Lab A as their top choice. Lab A's PI had several

active projects; during my year of observation, Lab A funded twelve students and two postdocs. In contrast, Lab B only funded four graduate students, and could not fund the one new student who expressed interest during my observations.

More research is needed to determine if “commercialist” scientists fund more students than their “traditionalist” colleagues (Johnson 2017), and how this affects research productivity and student professionalization. Students perform much of the benchwork in academic science, and the number of students a lab has shapes the work it can take on. This lab size difference would represent another instance of accumulated advantage. Educational spaces are also important sites in which norms are transferred from one generation to the next (Zucker 1977). Research suggests that postdocs working for faculty engaged in commercial research are likely to commercialize their own work in the future (Azouley et al. 2017). Patterns of innovators funding students may reproduce the gendered recruitment patterns that produce the macro-level gender patenting gap (Whittington 2018).

Space

Commercially active academic faculty may have better access to valuable space on campus. During my five years observing BRC, the faculty worked (and continually failed) to secure a physical space on campus. This failure was despite the fact that there was a new multimillion-dollar research institute focused on building UIRs and research commercialization on campus. Whole departments moved to the institute’s space during my fieldwork. Today there are over 200 faculty labs housed at the institute. As part of the

institute's mission to foster UIRs, wings of the building sat empty, ready for companies to rent out to work alongside university faculty and technicians trained to operate expensive equipment housed at the institute.

The institute director expected faculty housed in the institution to build UIRs. Dr. Diana Thatcher experienced hostility from the incoming institute director because her work is not innovation-focused:

“In the first six months I was [at the university] I felt in danger of ... [everything I'd worked for] going away,” she says. “The big one was lab space in [the research institute that housed several STEM departments on campus]. [The institute director] didn't want to give me lab space. He was hired after me, so I signed the paperwork and then he comes on board and he's got all these different ideas [for how faculty should be doing science]. He talked to me...in passing, saying he wanted to kick people out of the building if they're work is not translational enough...what the hell?,” she says, “I was new. I had been there a few months and he says this to me. I'm thinking, I'm not translational, I'm going to get kicked out of this building. What have I done? What have I signed up for?’ I sometimes feel like I don't belong [here].”

Another faculty member, also a woman but more applied in research focus, said:

Every month, [the institute] had us present data...[and] give a sales pitch...it was like every month, every week, they were asking, what have you published? What grants do you have? How many students? How many companies do you have? All these questions...I never felt like I was going to be kicked out of the building, but

other people did. That was just absurd. There was a lot of, how much are we supposed to fight to stay in this building? Is it ours? Is it not ours?...You feel like a bit of a puppet, a little bit like you're being moved around. You have to do things as part of [the institute].

The above quotes highlight the ways that space, as a scarce resource, can be used to drive certain for-profit agendas. Dr. Thatcher did not do “translational” work, which made her feel like she could lose her lab space. Ultimately, she transferred to a different university a year after I interviewed her. Her colleague, more commercially focused, never felt at risk of being kicked out herself despite recognizing the tight position some of her colleagues were in. These examples show how space can become tied to commercial expectations that administrators increasingly place on faculty. This prioritization will disproportionately benefit men.

DISCUSSION AND CONCLUSION

This article investigates: (1) how gender shapes who is included and excluded from innovation contexts, and (2) the material repercussions of exclusion. I find that gendered team and organizational processes around recruitment, division of labor, and visibility facilitate men’s continued integration in innovation contexts while simultaneously shaping barriers to women’s integration. Once in these spaces, men perform ‘inventor masculinity’ – a blend of hegemonic physical science masculinity and market competition – to navigate their inclusion in innovation contexts. Men perform inventor masculinity to access and wield male privilege in innovation contexts. Through

performing inventor masculinity, men scientists devalue feminine-typed expertise, practices, and experiences, which likely hinders women's integration into innovation spaces. Inventor masculinity may also be harmful for men, as it provides a narrow framework for acceptable ways to do masculinity in innovation contexts and facilitates the subjugation of non-hegemonic forms of masculinity in these spaces.

I began this article by laying out how university administrators' recent move to value research commercialization in tenure decisions unfairly benefits men by giving them security in a field of growing instability. I find that women's exclusion from innovation contexts facilitates men's social closure around valued resources like funding, prestige, students, or space. Thus, academic research commercialization is part of a broader gendered 'Matthew Effect' in science (Smith-Doerr 2011; Zuckerman 1977) in which male privilege begets opportunities for men scientists. Future research should critically examine the potential downsides for women operating in these innovation spaces, even when there are explicit commitments to diversity and equity in place. As I suggest above, the growing prevalence of research commercialization creates stability for men amidst a field of growing instability. More research on how the dynamics of research commercialization create security for men but not for women warrants further research.

Future research would also benefit from an intersectional analysis that focuses on how systems of oppression overlap to shape distinct experiences for academic scientists with distinct identities (Collins 2015; Crenshaw 1989; Glenn 2002). My findings from this chapter show how academic research commercialization reflects unequal gender dynamics found throughout society through team and organizational processes around

recruitment, division of labor, and visibility. Future research should analyze how these gender dynamics intersect with other aspects of social identity like race or nationality to shape inequalities among academic scientists. A recent report published by the Pew Research Center shows that, despite some gains on diversity, Black and Latinx scientists are still underrepresented in STEM disciplines like engineering (Fry et al. 2021). Scientists of color often lack adequate mentorship (Espino and Zambrana 2019), and a study of engineers of color demonstrates that a large portion (54%) do not feel aligned with their disciplinary community (Brown et al. 2013). Past studies examining the experiences of women also find that women of color experience unique forms of discrimination not experienced by their white women counterparts (Elliot and Smith 2004; Muhs et al. 2012; Ong 2005). Future research should interrogate how the compounding of race and gender discrimination in STEM shapes processes of privilege or exclusion around research commercialization.

Similarly, future intersectional analysis should also explore how gender and nationality compound to shape integration into innovation contexts. There has been a massive growth of international students getting their PhDs from U.S. STEM programs in the past two decades (Ruiz and Budiman 2018). But citizenship status opens and closes doors for research opportunities, with domestic students are eligible for certain types of funding that international students are not. How does the constraints around international student funding shape whether their PIs include them on innovation projects? And how do these dynamics intersect with systems of oppression like gender, race, or ethnicity that create barriers for integration in science? By addressing how nationality intersects with other systems of oppression in regards to research commercialization, sociologists of

science will better understand how privilege and exclusion play out in STEM training, and with what consequences.

[1] I have promised confidentiality to my respondents. All individuals and organizations names are pseudonyms and any identifying information has been redacted.

CHAPTER 4 FIGURES & TABLES

Table 4.1. Interviews with participants in two sites by position

	Biomaterials Research Center (BRC)	Soft Materials Research Center (SMRT)
Faculty	9	7
Graduate students	1	38
Undergraduate Students	3	0
Administrative Staff	1	1
Total	14	46
		Total Interviews: 60

Table 4.2. Interviews with participants by position and gender

	Women	Men
Faculty	4	12
Graduate students	16	23
Undergraduate Students	1	2
Administrative Staff	2	0
Total	23	37
		Total Interviews: 60

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