"If Chemists Don't Do It, Who's Going To?" Peer-Driven Occupational Change and the Emergence of Green Chemistry

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Abstract: Occupational membership guides what people do, how they think of themselves, and how they interact in organizations and with society. While a rich literature explains how occupations adapt in response to external triggers for change, we have limited insight into how occupational incumbents, absent external triggers, work to influence how their peers do their work. We investigate the emergence and growth of "green chemistry," an effort by chemists to encourage other chemists to reduce the health, safety, and environmental impacts of chemical products and processes. We find that advocates simultaneously advanced normalizing, moralizing, and pragmatizing frames for green chemistry and that each frame resonated differently with chemists in their various occupational roles. While this pluralistic approach generated broad acceptance of the change effort, it also exposed tensions, which threatened the coherence of the change. Divergent responses of advocates to these tensions contribute to a persistent state of pluralism and dynamism in the change effort. We discuss implications for theory on occupational change arising from our attention to internally-generated peer-driven change, heterogeneity within occupations, and change efforts that moralize occupational work.

Keywords: occupations, occupational change, occupational identity, professions, change processes, multivocality, pluralism, green chemistry, sustainability, grand challenges

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Occupations are central to the study and management of organizations, guiding what people do, the values to which they adhere and their social relationships and identities (Bechky, 2011; Van Maanen and Barley, 1984). Occupations also offer a crucial lens into organizational and broader social phenomena (Barley and Kunda, 2001; Bechky, 2011); changes in occupations frequently reflect broader changes in social values and norms (Goodrick and Reay, 2010; Lounsbury, 2001) and are both cause and consequence of organizational change (Chriem, Williams, and Hinings, 2007; Reay et al., 2013). Studies of occupational change have focused on how external triggers – including new technologies, regulatory changes, encroaching neighboring occupations, and organizational pressures – compel and shape change efforts (Bailey, Leonardi, and Chong, 2010; Goodrick and Reay, 2011; Kellogg, 2009; Nelson and Irwin, 2014). Yet, scholars have devoted much less attention to how change unfolds in the absence of such external triggers.

Attempts by occupational members to change their occupations absent overt external triggers are neither new nor rare. For example, a group of scientists founded the Federation of American Scientists in 1945, with the goal of leveraging science for peaceful purposes and preventing nuclear war. More recently, MBA students and alumni have worked to promote a commitment to the responsible and ethical creation of value among their peers (Anderson and Escher, 2010). While these moves may be broadly responsive to changing conditions, they are not directly triggered by regulatory, organizational, technological, or jurisdictional shifts. Instead, the impetus for change emerges from within the occupation and centers on its members' efforts to alter how peers think about and do their work.

Internally-generated, peer-driven efforts at occupational change likely unfold differently from those that are directly responsive to external triggers. Absent external triggers there is a diminished need to respond to a common "enemy," like an encroaching adjacent occupation, or to construct a common identity – mechanisms that prior work has associated with mobilization for occupational change (Bechky, 2011; Goodrick and Reay, 2010; 2011; Greenwood, Suddaby and Hinings, 2002). Internally-generated change efforts must therefore directly confront the diversity within occupations that reflects differences in how occupational members go about, understand and value their work (Wright, Zammuto, and Liesch, 2016; Leavitt et al., 2012). In turn, such occupational heterogeneity may complicate the process of generating occupational change, and alter the trajectories or outcomes of the associated change efforts. To build theory on this important process, we studied the development of an internally-generated and peer-directed occupational change to explore the research question: *how do members of an occupation initiate and sustain an effort to change how their peers think about and do their work?*

We studied an effort within the occupation of chemistry to develop "green chemistry." Green chemistry emerged in the 1990s, when a small group of chemists began advocating new practices that would enable chemists in academia and industry to reduce the environmental, health, and safety impacts of their work. On one hand, the change effort has met with apparent success: Ten years after the formal statement of 12 green chemistry "principles," a body of work comprised of nearly 4,800 academic papers, almost 1,000 documented industrial innovations, and 12,400 patented inventions had emerged. On the other hand, green chemistry advocates still lament that many of their peers fail to align with the change effort. As one said, "The only objection to green chemistry is from within chemistry."

Our analysis of extensive interviews, archival data, and observations reveals that advocates triggered change within the occupation through their *versatile framing* of green chemistry, presenting it in terms of concrete knowledge and work practices common to all occupational members, but simultaneously advancing different frames that specified the utility of making the change. These frames included: i) a *normalizing* frame, which positioned green chemistry as consistent with mainstream chemistry innovation; ii) a *moralizing* frame, which positioned it as an ethical imperative; and iii) a *pragmatizing* frame which positioned it as a tool that could help chemists gain leverage on problems they encountered in their day-to-day work. We also find that these frames enabled *role-centric mobilization* because they resonated differently with distinct occupational roles that chemists fulfilled. Yet, the associated diversity in work done under the banner of green chemistry also generated tensions that arose from chemists *experiencing frame incompatibilities*, which lead to simultaneous attempts by advocates to either tighten or sustain versatile framing. The change effort we unveil thus has a distinct character, in which diversity and dynamism are more salient and persistent than coherence and closure.

Our analysis has several implications for theory. First, we extend work on occupational change by uncovering a process through which occupational members generate and sustain change absent overt external triggers. Second, we show how occupational heterogeneity can enable and delimit change, complementing work focused on how occupational commonalities are leveraged in service of change. Finally, our work uncovers a paradox at the center of change efforts that seek to alter how peers think about and do their work, by showing how well-meaning efforts to "moralize" occupational work can heighten resistance, inhibiting the very changes that enable experts to address urgent societal problems.

Occupations and Occupational Change

As described by Van Maanen and Barley (1984: 291), *occupations* are characterized by "common tasks, work schedules, job training, peer relations, career patterns, [and] shared symbols." Members of an occupation form an *occupational community*, or a "group of people who consider themselves to be engaged in the same sort of work; whose identity is drawn from the work; [and] who share with one another a set of values, norms and perspectives that apply to but extend beyond work" (Van Maanen and Barley, 1984: 294-5). Thus, far from simply providing individuals with a set of tasks to make a living, occupations deeply permeate most every aspect of organizational and social life (Ashcraft, 2013; Bechky, 2011) and grant members important and resilient aspects of their identities (Goodrick and Reay, 2010; Leavitt et al., 2012).

It is not surprising, then, that members of occupations frequently resist and counter efforts to impose change on work practices, educational standards, or jurisdictional boundaries that stem from regulatory, technological, organizational or other occupational shifts. At times, resistance can seem futile, as when inexorable technological changes mechanize tasks and lead to "deskilling" (Braverman, 1974). For example, Nelson and Irwin (2014) describe the disappearance of elevator operators, bowling-pin setters, and street-lamp lighters in the face of technological change. Commonly, however, technology and other external shifts act as triggers that compel occupational members to respond and perhaps adapt (Bailey, Leonardi, and Chong, 2010; Leonardi and Barley, 2010).

Occupational Responses to External Triggers for Change

A rich literature on occupational change offers several mechanisms that account for how occupational incumbents respond or adapt in the face of external triggers for change. We summarize findings from studies that look at both professionalized occupations and nonprofessionalized ones, because the mechanisms of and impetus for occupational change has much to do with the identities, shared knowledge, norms and values that bind members, and relatively less to do with the more formalized arrangements within which these reside.[1] The

[1] Scholars of occupations and professions assert that "there are no fundamental distinctions to be found between a profession and an occupation which are inherent in the work itself" (Van Maanen and Barley 1984: 318). Similarly,

literature portrays three main mechanisms through which occupational incumbents respond to external triggers for change: i) they assert influence over their occupation's jurisdiction, practices, or educational standards; ii) they leverage opportunities to craft and legitimate a revised occupational identity; or iii) they institutionalize shifts occasioned by diffuse, emergent practice changes.

The first mechanism involves occupational members countering external triggers by asserting control over jurisdictional boundaries, work practices, or educational standards. For example, Goodrick and Reay (2011) document how new U.S. regulations after 1945 limited pharmacists' abilities to apply their specialized knowledge, while market forces routinized pharmacists' practices. These changes led pharmacists to become dispensers of mass produced pharmaceuticals and "count and pour pharmacy" emerged. In response, pharmacists leveraged their professional association to gain "control over entrance and educational standards" for the occupation (Goodrick and Reay, 2011: 393), helping re-establish them as knowledge specialists. In other settings, as Bechky (2011: 1159) observes, "members of occupational groups compete to influence institutional structures such as accreditation and legislation," as when optometrists lobbied for changes to prescription laws that enabled them to expand into ophthalmologists' task jurisdiction. At times, in fact, occupation members can attempt to coopt or control external triggers for change. For example, Starr (1982) shows how physicians adapted to Medicare and Medicaid by exerting control over the legislation. These instances of occupational change are associated with a clear "common enemy," be it in the form of regulation, a neighboring occupation, or corporate practices. The nature of the change effort also relies, at least to some

Abbott (1998: 432) encourages scholars to move beyond attempts to categorize work into professions, semi-professions, and non-professions, writing, "The professions all exist on one level … What really matters about an occupation is its relation to the work that it does."

degree, on an occupation's capacity to act in a coordinated and authoritative way against this "common enemy."

A second mechanism occupational members use to respond to external triggers for change is to craft and legitimate a revised occupational identity. In these cases, the response may be less focused on an external "common enemy," as above, and more focused on drawing on the occupation's history and normative roots to legitimate transformed occupational roles or practices in light of specific shifts in market, organizational, or technological conditions (Goodrick and Reay, 2010). For example, Greenwood and colleagues (2002: 75) found that an accounting professional association fostered a shift in the work accountants did and their jurisdictional basis, in part by showing the "continuity and alignment of change with the prevailing values and practices of the profession." In a less structured setting, when librarians found their identity as "masters of search" threatened by technological changes, they first rejected but eventually embraced seeing internet search as compatible with, and an extension of, their occupational identity (Nelson and Irwin, 2014). In sum, this second mechanism of occupational change relies less on the exercise of power to assert control, and more on members' capacities to discursively construct a compelling identity, and associated practices, that occupational members can buy into and enact in response to external triggers for change.

Finally, a third mechanism of occupational change is even less directive, and emerges out of occupational members' dispersed and sometimes improvisational practices that eventually coalesce. Again, this mechanism operates in response to specific external triggers, be it the imposition of a new technology that reshapes occupational tasks and interaction patterns (Barley, 1986), or an organizational merger in response to new market demands enabled by regulatory shifts (Smets, Morris, and Greenwood, 2012). However, rather than unfolding around a somewhat coordinated effort to counter a common enemy or craft a common identity, change happens through the dispersed, uncoordinated, everyday actions of practitioners of the occupation. For example, Barley's (1986) study of the introduction of new medical imaging technologies into two hospitals reveals that daily use of the technology generated larger patterns of occupational change, by shifting how radiology technicians did their work and how they interacted with once-dominant radiologists. More recently, Smets and colleagues (2012: 891) show how day-to-day improvisations of banking lawyers working to operate seamlessly across international borders gave way to a "shift in the German lawyer's occupational image… to cover [a] broadened scope of legal services and their increasingly proactive and client-centered commercial orientation." Importantly, these studies suggest that changes that emerge this way are more likely to take root "within rather than across the boundaries of an organization" (Smets, Morris, and Greenwood, 2012: 895).

In sum, the three predominant mechanisms for member-driven occupational change unfold differently, but each is generated as a response to an external trigger. By contrast, absent an external trigger, peer-driven occupational change – as the opening examples of atomic scientists and MBAs show – may be more visionary and opportunistic (i.e., taking the form of "what if we…?" or "could we be…?") as opposed to reactive (i.e., in response to "we can no longer do…" or "we must show that we are …"). Moreover, without the need to respond to a common enemy, the need to craft a common identity, or the need to improvise practices in response to new constraints, these mechanisms may well be irrelevant or ineffective. In fact, Greenwood and colleagues (2002: 74) assert that change may take a different form and be more challenging in settings where there is a "diversity of membership and lack of collective mechanisms."

Moving Away from Occupational Commonalities

Each of the mechanisms discussed so far relies on leveraging or discovering commonalities among occupational members, be they in the form of common commitments to jurisdictional boundaries, common elements of a shared occupational identity, or common practices that underpin the work across different settings. Yet, occupations are far from homogenous, and members' experiences of their occupational roles and identities vary (Bucher and Strauss, 1961; Freidson, 2001; Van Maanen and Barley, 1984). For example, Van Maanen and Barley (1984: 296) note that while outsiders may view commercial fishermen as relatively homogenous, "Traditional fishermen recognize differences between themselves and 'non-traditional fishermen' such as 'educated fishermen,' 'part-timers,' and 'outlaw fishermen.'"

Occupational heterogeneity has received limited attention in the literature on occupational change, perhaps because so many instances of change are studied in response to external triggers that tend to rally members around commonalities. Recent work, however, shows that heterogeneity within occupations can importantly influence how members think and act. For example, specialization among physicians leads clusters of specialists to develop customized occupational identities, with differences exacerbated by specialists' assignment to separate hospital departments (Wright, Zammuto, and Liesch, 2016). Thus, as Wright and colleagues (2016) note, "different specialists who share the same value at the macro level of the profession may interpret the profession's value differently in their everyday work at the micro level."

Moreover, occupations often interpenetrate, further complicating how peoples' experiences of their occupation shape their actions. For example, Leavitt and colleagues (2012: 1317) observe that "many employment situations now involve multiple occupational identities embedded in a single occupation; physician-HMO administrators, engineer-managers, and environmental scientist-actuaries." Similarly, Lampel and colleagues (2000) describe the "balancing act" that workers in the creative industries must perform, as in the case of filmmakers who serve as both producer and director. These studies suggest that actions are cued not by a stable sense of who one is as an occupational member, but instead by who one is in particular situations or when enacting particular roles. In other words, one's personal and situation-specific experience of an occupation helps "answer the question, 'What does a person like me do in a situation like this?'" (Leavitt et al., 2012: 1317-8).

Together, this work highlights how members of the same occupation may experience that occupation rather differently, especially as they perform different roles. In turn, this heterogeneity within an occupation also may influence how peer-driven efforts at occupational change are initiated and sustained. Unfortunately, how occupational change unfolds in the absence of direct external triggers, and in the face of occupational heterogeneity, is virtually unstudied. Our research explores this process.

Methods

Rationale and Research Setting

The emergence of green chemistry within the occupation of chemistry offers an excellent setting for exploring how occupational members seek to trigger and sustain a change in how their peers think about and do their work. Chemists share a common understanding of basic principles underlying the composition and properties of matter, and engage in common practices to accomplish chemical synthesis or design. In addition to these "common tasks," chemists' work possesses other hallmarks of an occupation, including common "job training, peer relations, [and] career patterns," (Van Maanen and Barley 1984: 291), specialized higher education, and regular interaction through conferences, publications and society membership (e.g., the American Chemical Society). Finally, chemists "share with one another a set of values, norms and perspectives" (Van Maanen and Barley, 1984: 294-5), such as a commitment to the scientific method, peer review, objectivity, an apolitical perspective on knowledge, and an assumption of a cumulative knowledge base to which any chemist can contribute if her or his work meets the appropriate standards of rigor.

In contrast to other accounts of emergence in scientific fields, such as biotechnology (Powell, Koput, and Smith-Doerr, 1996) and tissue engineering (Murray, 2002), green chemistry was not triggered by discrete scientific discoveries or inventions. Instead, it emerged as a grassroots effort by chemists to influence their peers to alter their work in accordance with "The 12 Principles of Green Chemistry" (see Appendix A). Thus, chemists themselves described green chemistry as a peer-directed change effort that "lacked the external incentives… that might motivate vigorous … take-up" (Iles, 2013: 476) and they noted:

> Green chemists have focused on other chemists and industrial corporations as important audiences, have invoked their own professional status as chemists to justify their work (rather than, say, as citizens concerned about the environment), and have used technical evidence …[to] resonate … with their peers (Iles, 2013: 467)

The 12 Principles were first published in a 1998 book, *Green Chemistry Theory and Practice*, written by two of green chemistry's earliest advocates, Paul Anastas and John Warner. These principles offered guidance that would improve the health, safety, and environmental impacts of chemical processes and products at various chemical lifecycle stages. In essence, green chemistry is an aspirational and visionary change effort calling for chemists to design chemical products and processes that reduce or eliminate the use or generation of hazardous substances, and hence reduce the harmful effects of synthetic chemicals on human health and the environment.

As mentioned, green chemistry prompted a substantial body of work – ten years after the principles were articulated, nearly 4,800 academic papers had been published, 1,000 industrial innovations were documented, and 12,400 patented inventions were described. The 2005 Nobel

Prize in Chemistry was awarded for work in green chemistry. On the other hand, one chemist, reflecting the sentiments of many others, observed that "There's been a general reluctance … to accept green chemistry as being proper science" [25]. In other words, green chemistry advocates were only partially successful in convincing their peers to adopt the change. Thus, green chemistry offers a rich setting in which to explore how occupational members seek to change how their peers think about and do their work, because it set in motion a process that was neither straightforward nor without opposition.

Data Collection

We designed our study as a longitudinal case study and took a multi-method approach. We began by reviewing key green chemistry publications, including Anastas and Warner's (1998) *Green Chemistry Theory and Practice*, early journal publications by these and other early advocates, two dissertations on green chemistry policy, and a handful of scholarly articles on green chemistry patenting (Nameroff, Garant, and Albert, 2004) and history (Woodhouse and Breyman, 2005; Sjostrom, 2006; Linthorst, 2010). Our review provided an overview of green chemistry, its origins, key events and participants. We then engaged in qualitative and quantitative data collection. We conducted the in-depth semi-structured interviews that form the core of our data, and built a database of scientific articles on green chemistry that documented the evolution of the scientific discourse and identified potential interviewees. We gathered additional primary data through naturalistic observation at workshops and conferences, which enabled us to speak informally with attendees and hear their conversation about the accomplishments of and challenges to green chemistry. Finally, we gathered and coded editorial articles spanning the entire history of green chemistry from 1996 to 2015, to capture how chemists and other observers of the occupation wrote about it over time. We elaborate on each of these data sources below and summarize them in Table 1.

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Semi-structured interviews. Informants' accounts of how they engaged with green chemistry form the heart of our data. We conducted a total of 46 interviews with 38 individuals in three waves between 2009 and 2015. All interviewees had been trained as chemists and they worked in academia, industry, and, in a handful of cases, policy settings. Our first informants were recruited from professional networks of the chemists on our author team, who knew green chemistry advocates. At the end of every interview, we asked informants to suggest colleagues who could provide a valuable perspective on the development of and challenges to green chemistry. We solicited names of chemists who could offer potentially diverse perspectives, including chemists working outside of North America and those employed in industrial as well as academic settings. Our sampling approach was theoretical rather than representative, as we were interested in learning about the emergence and development of green chemistry from a broad array of informants within the occupation.

Our first wave (24 interviews with 22 individuals) occurred during a nine-month period in 2009 and 2010. Interviews lasted from 25 minutes to two hours, with most lasting around one hour. All but one were audio recorded and transcribed.[2] We used an interview guide (see Appendix B) to structure our questioning. Questions probed informants' personal involvement with green chemistry, their perceptions of its growth and evolution, their sense of opportunities and barriers to growth, and how they and others used the label "green chemistry." We elaborated our questions for certain interviewees to focus on their particular experience (e.g., journal editor). As is typical in inductive research, as interviewing proceeded, our analytical reflections as an

[2] In this case, the interviewee declined to be recorded but allowed us to take detailed notes.

author team led us to include specific probes to elicit added detail. For example, to inquire into whether and how green chemistry altered how informants practiced chemistry, we added the probe, "Tell me more – how did your early interest [in green chemistry] change how you did research?"

We conducted a second wave of interviews in 2013 in order to deepen our understanding of themes arising from initial analysis of the first wave interviews. Specifically, we sought to better understand how these chemists applied the principles of green chemistry, how they thought about themselves as chemists, and their understanding of resistance to green chemistry among chemists. The 12 individuals whom we contacted for these second-wave interviews included four from our original sample and eight new people. Including repeat interviewees enabled us to assess and build upon some of our initial analyses, while adding new interviewees expanded our sample. (We identified new interviewees through a green chemistry summer school, thus capturing a sample of "second-generation" green chemists whose reasons for affiliating may differ from those of earlier adopters.) Appendix C shows the 2013 interview guide. The second-wave interviews lasted about 30 minutes and were recorded and transcribed.

Finally, we conducted a third wave of interviews in 2015, comprised of 10 chemists, eight of whom were new informants and two of whom had been interviewed in both prior waves. Whereas our first two waves focused on green chemistry advocates and adopters, the third wave focused on skeptics and others who did not explicitly label their work as green chemistry. We identified these chemists by soliciting names from our other informants and by analyzing our database (described below) to identify individuals who, for example, published work that aligned with the 12 principles yet eschewed the label and/or association with green chemistry. Our questions in this round thus probed general impressions of green chemistry, and reasons for associating (or not) with green chemistry. Appendix C contains the wave three interview guide. These interviews lasted between 30 and 60 minutes and were recorded and transcribed.

Editorials and commentaries. To supplement the perspectives provided by our interviewees, we gathered green chemistry editorials and commentaries that appeared in scholarly journals (e.g., *Science*, *Nature*, *Green Chemistry Journal*) and those associated with chemists' occupational associations (e.g., the American Chemical Society's journal *Environmental Science & Technology*). We searched the SciFinder Scholar and Web of Science databases using the phrase "green chemistry" and then filtered to extract the following article types: editorials, commentaries, letters, viewpoints, reflections, and perspectives. In an attempt to build this dataset beyond advocacy pieces, we then conducted additional searches in SciFinder Scholar, Web of Science, Google Scholar, and a custom search tool available through our university library. These searches identified articles tagged with "green chemistry" and terms such as "resistance," "challenges," "barriers," and "limitations." In total, these searches yielded 1,183 documents. A chemist on our author team reviewed the titles and removed technical papers, retaining 300 documents. She then examined each document and removed those that had little to do with green chemistry, retaining in 132 documents. Finally, another co-author reviewed these 132 documents to identify ones that specifically shed light on how chemists worked to convince their peers to adopt green chemistry or, conversely, the objections raised or tensions revealed. This winnowing process yielded a final dataset of 84 editorials and commentaries.

Publication Database. To complement the aforementioned data, we built an extensive database of peer-reviewed green chemistry research publications. Whereas the editorials consisted of "opinion" pieces, the research publications reported the actual science of green chemistry. We constructed this database by searching the American Chemical Society's

SciFinder Scholar archive with 10 keywords that chemists on our author team identified as having the potential to locate scientific green chemistry publications. Using a broad set of keywords cast a wide net by limiting false negatives, but generated a large number of false positives. A chemist on our author team proceeded to inspect each publication to assess whether it employed at least one of the 12 green chemistry principles. Our final database contains 6,394 scientific publications that include the term "green chemistry" and/or employ at least one of the principles. These data provide a more complete view of publication activity than would use of the "green chemistry" label alone and allowed us to identify chemists for the third wave of interviews who engaged in green chemistry practices without claiming the label or, conversely, who claimed the label but did not actually engage in the practices. (See Nelson et al., 2014 for further details on this database.)

Data Analysis

Throughout the data collection period, the authors engaged in regular conversations to reflect on what we were hearing and seeing, puzzle over what it meant, and connect it to constructs in the literature. We began coding by reading interview transcripts and marking potential codes in the margins. At this stage, some important themes emerged. First, we were struck by how advocates described the importance of a principles-based change and how they spoke of this enabling them to recruit chemists with diverse motivations. At the same time, all interviewees mentioned tensions they faced in doing or promoting green chemistry.

Often, informants accompanied these reflections with references to and descriptions of different roles that chemists might perform. Ashforth (2001) defines a role as a "position within a social structure" such as a work organization (e.g., an accountant) or a family (e.g., a mother). Places, times, tasks or other boundary constructions delineate roles and their performances. People's role performances, in turn, inform their goals, values, norms, and interaction patterns in work settings (Goodrick and Reay, 2010). As noted earlier, members of an occupation may delineate the boundaries of roles in a manner that is relatively obscure to outsiders (recall Van Maanen and Barley's (1984) description of how fishermen differentiate themselves). Accordingly, we attended to how our informants differentiated roles within their occupation, instead of relying on established assumptions about the role structure of chemistry. Our informants said that chemists performed the following roles: researchers or innovators in academic or industry settings; educators or communicators; and "problem solvers" as they attended to constraints that impeded their performance of other roles. Of course, there was variation within these roles and interviewees did not indicate that these were the only possible roles for chemists. However, they indicated that differences among these roles within the occupation were significant, and salient towards understanding how advocates worked to promote green chemistry to their peers.

We used ATLAS.ti to capture and systematically code all interview data. While we began with a preliminary list of codes gleaned from the margin notes, several rounds of coding and the addition of new data led us to add to, alter, and replace these codes as we proceeded. We initially focused on the interviews with early advocates to begin to understand how they aimed to encourage a change toward green chemistry. This yielded insight into the role of the 12 principles, and the pluralistic manner in which advocates presented green chemistry to their peers.

As we added interviews and engaged in further rounds of coding, we came to see that advocates used different "frames" or ways of presenting green chemistry and its potential appeal. Frames are jointly-constructed accounts or meanings often associated with a particular line of action (Benford and Snow, 2000; Kaplan 2008; Cornelissen and Werner, 2014). Specifically, we found three broad frames reflected in our data – "normalizing," "moralizing," and "pragmatizing."

(We elaborate on these frames in our findings.) We also coded for how chemists responded to these frames, noticing that these frames appeared to resonate differently with different roles within the occupation, and that green chemistry advocates spoke of using the frames accordingly. For example, the statement "[students] are more environmentally conscious … and we have to show them there is an alternative to [chemistry] that pollutes and it's called green chemistry" [24][3] was coded as using a moralizing frame and directed at chemists in their role as educators interacting with students.

In addition, we coded for various tensions informants described and for the actions they and others took to manage these tensions. We noticed that some tensions cohered around incompatibilities among the frames used to present green chemistry and we revisited our data to understand these and characterize them as tensions of quality, commitment and complexity (see findings section for full description). We noted two primary responses to these tensions, including one which sought to tighten the frames to reconcile the tensions, and another aimed at sustaining all three frames.

Finally, we turned our attention to the 84 editorials and commentaries. One co-author read the complete set of editorials to explore how green chemistry was framed in these outlets, whether and how the framing shifted over time, and how tensions and responses were discussed. He systematically coded every document, working chronologically, and applied the same codes developed through our interview coding. We used the coded editorial data to corroborate and contextualize the findings from our interviews.

Throughout our coding we paid attention to the development of green chemistry over time, and attempted to map the use of frames, emergence of tensions, and responses to these tensions

[3] We use a unique, randomly assigned identifying number for each interviewee in reporting our findings.

to a chronology of the change effort. This helped us see how green chemistry emerged and evolved through a cumulative process, in which early mechanisms to initiate the change were sustained even as they lead to further tensions and efforts to manage them. It did not, however, reveal a linear process progressing cleanly from stage to stage, nor one that reached a stabilized state. Instead, at the collective level, the effort to create change toward green chemistry became more complex over time as tensions were manifest and different responses to them emerged. Simultaneously, at the individual level, any given chemist exposed to green chemistry encountered essentially the same set of frames across the entire time period we studied. We parse our explanation of this cumulative process into distinguishable, yet often intermingled phases, which are demarcated by new layers of experience or action.

The Emergence and Evolution of Green Chemistry

During green chemistry's initial emergence, advocates presented the change to their peers in terms of concrete work practices, yet also invoked several distinct frames that specified the utility to chemists of adopting these practices. We call this simultaneous use of multiple different frames *versatile framing*. Different frames resonated with chemists in their different roles, attracting individual chemists to green chemistry through *role-centric mobilization*. Versatile framing and role-centric mobilization, which persist throughout our study period, together gave rise to considerable diversity in what was done under the banner of green chemistry. This diversity led chemists to experience tensions tied to the incompatibilities among the frames (*experiencing frame incompatibility*), which also persisted. Experiencing frame incompatibility led some green chemistry advocates to attempt to minimize tensions among the frames by asserting the primacy of one frame (*tightening*). Yet other advocates resisted these moves, working to sustain pluralism through the continued use of multiple frames (*sustaining*). The move towards green chemistry is thus characterized simultaneously by growth and by contradictions surrounding how to sustain this growth. Below, we explain the progression and accumulation of the mechanisms that initiated and sustained this change effort.

Versatile Framing: Advocates Present Concrete Practices Yet Multiple Distinct Frames

As chemists themselves, green chemistry's early advocates viewed chemistry as an occupation that was slow to change. For example, one informant reflected that the core content of chemistry curricula is "what [a chemist] learned from their professor and they're passing on to their students," and added, "[our core chemical] reactions are all named after dead people" [22]. Another interviewee shared how he felt in the early 2000s that green chemistry was not being adopted quickly enough. His colleague, he recalled, attempted to cheer him up by saying, "It took polymer chemistry over 50 years to be integrated into academic departments, … [and] it took analytical chemistry about 80 years to be accepted …I think that we're doing pretty good" [32]. Green chemistry advocates thus understood that their efforts at generating occupational change would be challenging, given the historic pace of change and occupational members' reticence to alter core practices in chemistry.

Against this backdrop, green chemistry's earliest advocates sought to initiate change by lowering the effort their peers needed to expend to adopt green chemistry. Through *versatile framing*, advocates presented green chemistry as a set of principles concretely tied to core occupational knowledge and work practices, yet associated its appeal with one of several distinct frames. One chemist referred to the deliberate strategy of framing green chemistry as useful in many ways as an "intellectual flypaper" strategy, as it sought to capture the interest of chemists in different, perhaps multiple, ways, and made it difficult for chemists to become "unstuck."

Critical to versatile framing was portraying the change in concrete terms related to core knowledge and practices familiar to all occupational members, making it easy for them to see the connections to their day to day work. Early advocates established the 12 principles of green chemistry, which were straightforward for practicing chemists to apply. For example, one principle advises chemists to select innocuous solvents or to avoid solvents altogether for chemical synthesis. One chemist noted how the principles could guide peers' choices about chemical synthesis, as they "define[d] a set of criteria and scientific principles to deduce, from the many things that you can do, … which ones have an impact on sustainability" [34]. Another explained, "This was something that could be taught in a chemistry class. … [and] tied to the nuts-and-bolts molecular level of how do you do something" [38]. Ease of applying the principles was emphasized by early advocates who urged that they be seen as tools, not rules to be dogmatically applied. One recalled, "We never said 'Thou shall do this'" [38]. Another spoke of how she attempted to engage peers in her company by responding to their concerns ("That doesn't really apply to me, I'm not making small molecules," or "I'm stuck with this process") and saying "There may only be one or two principles that you're really going to be able to do much with, but [green chemistry] applies" [10].

While encouraging peers to be guided in their work by any (or several) of the 12 principles, advocates also used three distinct frames – normalizing, moralizing, and pragmatizing – that offered different reasons for a chemist to find the principles useful. Initially, advocates promoted these frames through social ties rather than a more coordinated top-down effort, despite the establishment of several organizations that served to facilitate information exchange about green chemistry and encourage its practice. One interviewee's comment was representative of others in expressing early advocates' preference for how green chemistry was presented to peers. She said, "We can't really have the same people doing the same thing. We have to sort of lose control of it in a sense." [35] In other words, she asserted that the success of green chemistry required the involvement of new chemists approaching green chemistry in new and different ways.

Using a *normalizing* frame, advocates presented green chemistry as consistent with mainstream chemistry, associating it with core norms around discovery, design, and optimization. Normalizing promotes activity as "normal science," by referencing a groups' accepted "norms as a basis for action" (Maguire and Hardy, 2013: 240). An early article asserted green chemistry "is connected with … issues concerning synthesis that [are] typical of chemistry. To discover, improve and optimize synthesis pathways has always been a main objective of chemical research." (Böschen, Lenoir and Scheringer, 2003: 100). Indeed, advocates positioned green chemistry as having a significant role to play in accelerating discovery of new chemicals and processes. As one chemist explained, "there [are] only about 120 framework molecules that everyone uses. And that's it. We're not exploiting chemical diversity. … green chemistry [is] a way of innovating in chemistry" [14]. In addition, green chemistry was referred to as a process of design. One chemist said "green chemistry is the idea that you can design hazards out... It's a frontal assault on the problem" [3]. Advocates also normalized green chemistry by connecting it to the optimization of manufacturing processes. An industry chemist observed that, thinking as a green chemist, "you can get high yield and high quality [products] because you really understand the fundamental chemistry" [24]. Use of a normalizing frame thus attempted to align green chemistry with long-standing norms and goals in the occupation.

Green chemistry advocates also advanced a *moralizing frame*, which presented green chemistry as an ethical imperative, associating it with what chemists ought to do to reduce the impact of their work on environmental and human health. Framing an issue as moralized "refers to the decision to couch [it] … in moral or ethical terms when communicating about it to others"

(Kreps and Monin, 2011: 103). Advocates presented green chemistry through a moralizing frame by emphasizing chemists' opportunity to deliver social benefits by creating less-harmful chemicals and responsibility to take ownership of the impacts of their chemistry, connecting these possibilities to chemists' unique ability to design molecules and the reactions that make them. Speaking about the social benefits, one chemist asserted:

> Instead of just using the same reactions that we have used for 150 years, [we now are] recognizing that there may be alternatives that are better for human health and [the] environment …. Before we reach for that heavy metal catalyst, we can see if there is a better way [6].

Other efforts at moralizing emphasized chemists' responsibility to account for the environmental and human impacts of their work. For example, an industry chemist said:

> There are product lines or chemistries that people had concerns about, that were under attack… [and we can use green chemistry to ask] "Alright, going forward, if we're going to do this smarter, better, how would we do it?" [10]

Some confronted chemists' unique abilities and moral responsibilities more starkly. One advocate said, "Here's the beautiful thing about [green chemistry] – it's actually about thinking about how we can protect life. Because that's the power we've got – the ability to wreck life" [23].

Finally, advocates used a *pragmatizing frame*, which presented green chemistry as a tool that could help chemists gain leverage on problems they encountered in the day-to-day course of their work. Work in any occupation is "localized [and] embedded" in other facets of day-to-day organizational life (Carlile, 2002: 543). For example, chemists face budget constraints, regulatory limits, and/or classroom capacities as they go about their work. Advocates used a pragmatizing frame to demonstrate how green chemistry might help with these challenges. One explained that, for industry "instead of the stick, it's the carrot. … [we tell companies that by adopting green chemistry] your destiny is more in your hands rather than in the regulator's hands." [3] Editorials, as well, stressed the attendant benefits of firms adopting green chemistry:

> Unlike exposure controls[4], that have been developed historically, Green Chemistry can impart added performance, added capabilities, and added efficiencies to the product or process … at the same time it addresses the environmental and human health concerns. (Manley, Anastas, and Cue, 2008: 744)

In academic settings, green chemistry also was framed as a way to address practical challenges. For example, advocates shared their experience that green chemistry could "make [teaching] laboratories greener or safer, [so chemistry departments] could potentially handle more students in the laboratory" [1], in part by eliminating fume hoods needed to remove harmful chemicals.

In sum, green chemistry advocates sought to influence their peers by presenting green chemistry as a set of principles concretely tied to core occupational work practices of chemical synthesis, design, and manufacturing. Moreover, they used distinct frames – normalizing, moralizing and pragmatizing – to demonstrate the utility to chemists of doing green chemistry. Together these activities contributed to the versatile framing of green chemistry, demonstrating that it could be widely applicable to many chemists, yet appeal to individual chemists in distinct ways.

Role-Centric Mobilization: Distinct Frames Resonate with Chemists' Different Roles

As advocates used the three frames to articulate why their occupational peers might find the 12 principles appealing, they found particular frames resonated most strongly with chemists as they fulfilled specific roles. Specifically, the *normalizing* frame resonated primarily with chemists in their role as *innovators*; the *moralizing* frame resonated primarily with chemists in their role as *educators and communicators*; and the *pragmatizing* frame resonated primarily with chemists in their role as *problem solvers*.

Advocates had recognized which frames resonated with which roles, and spoke of using this knowledge to tailor their messages. For example, one said "I have words and terms around the

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[4] Exposure controls aim to protect workers from hazardous chemicals, rather than eliminating the hazard itself.

subject [of green chemistry] that I probably change every time somebody asks me … [because] it's based around sort of blending it in" [25]. Similarly, another advocate stated, "the way people come to green chemistry can be very diverse" [32]. He explained:

> There are people who are motivated to be in chemistry…because it's a great scientific challenge. You need to meet [those] people where they are and say, "Here's why green chemistry is a great scientific challenge." … There are people who take up [chemistry] … because it's about problem solving. You want to show them why this is a more elegant solution. Then you can go to people who are educators, [and show them] that this is a way of reaching students, … or [go to] business people [and show them] why this is more profitable. The nature of green chemistry doesn't change [but] tapping into the different motivations … is something we've tried [to do] quite actively over the years.

Thus, advocates first discerned and then put into effect an alignment of the three frames with specific roles, enabling *role-centric mobilization*, which contrasted with mobilization through a blanket appeal or common frame (Benford & Snow, 2000).

Normalizing frame resonates with innovator role. A normalizing frame, which associated green chemistry with chemists' core scientific pursuits of discovery, design, and optimization, resonated with chemists in their role as innovators. Chemists see themselves as innovators who invent fundamentally new chemicals, syntheses, or applications for chemistry, and develop and modify processes for manufacturing chemical products. Academic chemists and industry chemists each perform, in different ways and degrees, this innovator role. By presenting green chemistry as attuned to "normal" chemistry, advocates valorized the skills and practices of chemists as innovators. For example, an early editorial stated, "green chemistry has demonstrated how fundamental scientific methodologies can protect human health and the environment" (Anastas and Kirchoff, 2002). One advocate recalled tailoring his talks to academic chemists, who saw themselves as innovators, explaining, "my lectures, [were] about two minutes of really hard hitting 'here's how bad things are,' and then 58 minutes of [showing] green chemistry utilizes the same brilliance and innovation" [32] that underpins chemistry.

This resonated strongly with some chemists in their roles as innovators. As one academic chemist recalled, "we discovered that you could do organic chemistry that you couldn't do using … the normal solvent approach. … [Our] innovation is higher and [we] can publish in better journals" [29]. Similarly, an industry chemist reflected, "[Green chemistry] does force you to think about chemistry differently … and anytime you're forced to do that, you ultimately get yourself into situations of innovation" [24]. Thus, these interviewees indicated that they valued green chemistry for its innovative potential.

Moralizing frame resonates with educator/communicator roles. A moralizing frame resonated with chemists when they performed roles where they became spokespeople for chemistry, because this frame helped them speak to outsiders' concerns over chemistry's safety and impacts. For example, academic chemists in their role as educators found they could use green chemistry to connect with students. One explained the appeal of a green chemistry lab course, saying "I think it really connected to them as human beings." He reasoned that, as opposed to "an organic laboratory class that nobody is interested in, [students] were excited … because we were talking about … the way things need to be," adding, "and maybe they'll be the one that makes the difference" [1]. In fulfilling their roles as communicators to the public, consumers, or other potentially critical audiences, chemists also found resonance with the moralizing frame. For example, one industry chemist remarked:

> [Chemists are] tired of having chemistry kicked around as being somehow not responsive to human needs … Green chemistry feeds an internal need to be able to feel that they're doing something that is responsible and worthwhile [17].

Finally, as implied in the quote above, the moralizing frame resonated with many chemists not simply for instrumental reasons of relating to students or the public, but because they found it appealing to think about their science as benefitting a diffuse "audience" (planet and people) to whom they felt accountable. This was particularly appealing to students who were aspiring chemists, intensifying the salience of the moralizing frame for chemists performing the role of educator. For example, one junior faculty member recalled, "I went to graduate school as a synthetic chemist, so making new chemicals was my whole thing … [but] green chemistry changes your perspective … from 'how do we make this brand new thing?' to 'what's going to be its environmental impact before we start?'" [18]. Another interviewee explained, "the passion that [green chemistry] practitioners … have for the subject is different from the passion that people have about other disciplines… It's not just passion for the science, but passion for the outcome" [3]. Thus, in their outward-facing roles, chemists were attracted by the moralizing frame, which associated green chemistry with responsible chemistry.

Pragmatizing frame resonates with problem-solver role. As chemists performed roles in which they tackled practical problems – which might be peripheral but nonetheless important to attaining their research, educational, or manufacturing goals – the pragmatizing frame resonated. For example, one interviewee reflected, "you find … people are [using green chemistry] … because [otherwise] it's too expensive to get rid of the waste, or it's too expensive to run the fume hood" [10]. Thus, the motivation is tied to prosaic everyday problems that chemists confront rather than to innovation, education or communication. As another example, a chemist who had heard of the potential for green chemistry to make his university's teaching labs safer realized that eliminating the need for certain safety equipment also increased the student capacity of the lab. Accordingly, he had seized the opportunity to teach a green chemistry lab course in order to make his teaching load manageable. At another research university, green chemistry was embraced by the Dean of the College of Chemistry when he realized that "incorporating green chemistry into the undergraduate curriculum was something that helped [with the] fundraising" [15] needed to remodel undergraduate labs, an otherwise unpalatable fundraising pitch.

Similarly, in industry settings a pragmatizing frame resonated with chemists who faced other practical challenges, like curbing manufacturing costs. Commenting on the use of green chemistry in the pharmaceutical industry, an industry chemist observed:

> In most green chemistry applications, the mass intensity is reduced. This corresponds to a lower cost since fewer amounts of raw materials are used to make the same product. The less amount of raw materials used creates a domino effect in terms of benefits, i.e., reduced time to handle the material, simpler operation, less waste generation, less waste treatment and disposal, etc. (Kang, 2010: 1029).

In sum, the pragmatizing framing resonated with chemists as they confronted practical problems in their everyday work.

Experiencing Frame Incompatibility: Tensions of Quality, Commitment and Complexity

Because advocates had advanced green chemistry through versatile framing – focusing on principles that exploited common occupational knowledge, as refracted through distinct frames that were aligned with different roles – a diverse community of chemists emerged who were all in some way engaged in green chemistry. Not surprisingly, within this community lay diversity in chemists' motives. As one interviewee said:

> People were attracted to [green chemistry] for whatever reason ... Some people saw it as an incredible intellectual challenge. Some people saw it as a new way of recruiting new people into the sciences. … I look at everybody in the field and I would be really hard-pressed to categorize … I don't know that any two people have the same reason [38].

Echoing that green chemistry's appeal reflected how chemists saw themselves, one quipped:

> When I talk about [green chemistry] in presentations … I get three reactions. I get a group of people [who] don't care because it isn't germane to their immediate research interests. I get a group of people [who] are totally and utterly depressed. And I get a group of people who are so inspired that they want to go off and change the world [14].

An editorial written eight years after the publication of the 12 principles reasoned that green chemistry's pluralism was perhaps inevitable given chemists' specific pursuits:

> It is surprising how diverse the answers can be when executives, engineers, … and chemists are asked the seemingly simple question "What is Green Chemistry?" Perhaps this should be expected considering that individual priorities change based upon a specific endeavor, altering the focus of Green Chemistry (Tucker, 2006).

These variations also exposed *frame incompatibilities*. Incompatibilities were experienced as tensions that chemists encountered as they made sense of the various actions taken under the banner of green chemistry. Importantly, because the different frames resonated with different *roles*, tensions could be experienced *within the individual*, for example, as she navigated several roles she performed as a chemist. Moreover, tensions arose *among chemists* when their understandings of green chemistry and its utility and application aligned with different occupational roles. Finally, the tensions served as reasons that dissuaded some chemists from adopting green chemistry.

In this section, we explore three tensions revealed by our analysis: i) *a tension of quality*, which arose through incompatibilities experienced between the normalizing and pragmatizing frames, ii) *a tension of commitment*, which arose through incompatibilities experienced between the pragmatizing and moralizing frames and iii) *a tension of complexity*, which arose through incompatibilities experienced between the moralizing and normalizing frames.

Tension of quality. The tension of quality arose when chemists, in their role as innovators, found their interpretation of green chemistry at odds with those acting in the role of problem solver. In other words, the normalizing frame, which resonated with the innovator role, was not fully consistent with the pragmatic frame, which resonated with the problem-solver role. This surfaced, and exacerbated, tensions between chemistry as cutting edge innovation and chemistry as applied problem solving. An industry chemist explained, "There's an elitism particularly among the academic community. [Chemists say] 'We do basic research… we don't do applied stuff,' [and] … 'Green chemistry I guess is for those folks who can't come up with better ideas'" [10].

Others argued that to the extent that green chemistry was seen as useful in solving practical problems, it was actually *less* well received by some those who defined themselves primarily as innovators, suggesting a persistent tension between regarding green chemistry as a vehicle for innovation *and* as a useful tool to advance other aims. One interviewee asserted that the relatively rapid uptake of green chemistry among educators, including those at liberal arts colleges where low budgets and lack of lab spaces made traditional chemistry education challenging, worked against the message that green chemistry should be regarded as cutting-edge science. He reflected on this, saying, "the intellectual merit became questionable because [green chemistry] was excelling at education" [38]. Another pointed to the tension of quality arising when research done for pragmatic reasons was tagged as green chemistry:

> The ionic liquid [research topic] .. [is an] example where people are doing research that's really focused on solving a particular problem, and then somebody put a green wrapper around what they've done … but the intent isn't green [3].

As green chemistry research publications grew, this growth seemed to exacerbate the tension of quality because some of it was seen as an attempt to build chemists' careers through added publications, rather than an attempt to conduct the very best science. One chemist observed:

> There are a lot of papers out there, you know, people reporting the 57th reaction is possible in supercritical CO_2 [an important green solvent]. Okay, that's exciting for reactions number 1, 2, and 3, but once you get to the 57th reaction nobody cares anymore. We don't publish papers – [saying] "Hey, look this reaction works in benzene [a traditional solvent] - woo hoo!" …There is a lot of stuff getting published under the name green chemistry that really shouldn't have been published under that name or, perhaps, at all. And that's hurting us [34].

An informant from a top research university explained that the tension of quality "makes [green chemistry] harder to adopt … because [some chemists] just feel like it's not rigorous" [15]. In this way, the tension of quality was not only experienced among chemists who were engaging in green chemistry, but also influenced how non-adopting chemists valued green chemistry.

Tension of commitment. The tension of commitment arose when chemists, in their role as problem solvers attracted to the pragmatizing frame, found their interpretation of green chemistry at odds with those of chemists acting in a role of educators or communicators, to whom the moralizing frame appealed. The tension revolved around the sense that, in line with the moralizing frame, one should *always* use green chemistry to guide one's chemistry, versus, in line with the pragmatizing frame, that it was acceptable to use green chemistry only when it supported other goals. As one chemist said, the moralizing frame could signal that chemists should be "doing all [their work] for greenness" [11]. Another reflected, "some green chemists … will tell you there's a need for revolution and we need to wipe the table [clean] and prevent the use of this, that and [the other chemicals]" [7]. However, such an approach was fundamentally incompatible with a pragmatizing frame, which permitted chemists to make tradeoffs among various goals or to use green chemistry to advance other, primary, goals.

Citing one appeal of a pragmatizing frame, saving money, an interviewee explained the difficulty for some industry chemists to live up to the ideals advanced by a moralizing frame:

> Anything to do with waste streams has been enthusiastically embraced by industry because there is a direct, straight-line connection to profitability. [But imagine] I make PVC for a living … and my process is really efficient, I've gotten rid of most of my waste streams. [And] now you tell me that my PVC is the problem? … Don't tell me to get rid of [PVC] … [That's] green chemistry's industrial glass ceiling. There is only so much improvement these guys can stand [36].

Another industry chemist remarked that, while green chemistry appealed within his company, "We were more driven by the opportunities in process [optimization] than we were in the ability to change [our] chemistry because of the nature of our business" [14].

Sometimes the tension over commitment was felt within a single individual performing different roles. For example, a chemist who became a leader green chemistry education, but who initially introduced it to solve a lab space constraint, admitted to feeling "sort of apologetic because my research was divorced from my teaching." He explained that his research lab was "working … with toxic heavy elements, and … with organic solvents instead of in water" [1].

In sum, while early advocates emphasized the flexibility of the green chemistry principles and the acceptability of using only one or a few of these as guides, the moralizing frame suggested a degree of commitment that was uncomfortable and perhaps impossible for some chemists to live up to, given their use of green chemistry as a practical tool to solve problems.

Tension of complexity. Finally, the tension of complexity arose when chemists in their role as innovators, for whom the normalizing frame appealed, found their interpretation of green chemistry at odds with others acting in the role of educators or communicators, for whom the moralizing frame appealed. The dilemma here is captured not in the *degree* to which chemists might use the principles of chemistry as guides to their work (as in the tension of commitment), but rather in the actual *capacity* of the green chemistry principles to capture the complexities and nuances involved in developing chemical products and processes that were safer and more environmentally benign. One interviewee summed up the tension this way:

> Some [green chemists] are seen as extreme people. …A small number of them tend to be very in people's faces and I think that's been a turnoff for researchers in the larger community. I'm not even talking about industry now…. People who are scientists are not particularly interested in zealots. They really want to know that it's sound science and they don't want to view it as … a crusade [26].

Even early on, advocates had foreseen the risks associated with using a moralizing frame when chemistry itself was a complex science. One commented, "There was a feeling that 'If I'm not doing green chemistry I must be doing red chemistry.' You're deliberately making a lot of people's work unacceptable" [25].

Central to this tension was chemists' recognition that green chemistry was very difficult. One academic chemist explained that a moralizing frame might "alienate the really gifted chemists who realize how difficult it is," and elaborated:

> [These chemists] aren't opposed to green chemistry ... but they understand how incredibly complex it is. They psychologically recoil when they see somebody get up and … accuse people of being irresponsible for not doing it .... So it actually does institute a rift between those really highly technically-skilled people who are interested in green chemistry but not champions of it, and the zealots [3].

Chemists who hesitated to label their work as green chemistry experienced this tension, and spoke of how doing cutting edge chemistry often demanded using materials or processes that were not "green." One openly affirmed, "certainly not everything that we do [in the lab] would be considered green" [11]. Another explained that an unwavering moral commitment to green chemistry would "remove degrees of freedom" [in material or process choices] that were potentially important to advancing science [15]. These chemists also expressed frustration that an association with green chemistry immediately focused attention on the environmental aspects of their work, detracting from an appreciation of the novelty of the chemistry itself. One explained:

> If you don't say anything about green chemistry, people say "your work is great." The moment you're somehow connected with green chemistry, now people say, "Okay, you have this problem, [and] you have this problem." [9]

He elaborated, "They want [it] to be perfect… But sometimes for very new results… it cannot be perfect," and added, "[the papers we publish] in green chemistry journals, [are] … the less creative of my research because … we need to be perfect [in the green aspects]."

Thus, these chemists were sympathetic to the moralizing frame, but asserted that there were limits to how "green" their work could be. One interviewee said, "I think it's more of a philosophy of constantly improving rather than [saying], 'I want to do everything in water [as a solvent] or … so it would be absolutely non-toxic.' We cannot do that" [7]. Another said, "[In our lab] we let green chemistry … guide what we do, but we don't let it define who we are" [11].

In sum, many chemists experienced the tension of complexity as they encountered the inherent challenges working in their roles as innovators, even if they saw green chemistry as the right thing to do. As one chemist said, “There are often tradeoffs between toxicity, efficiency, end of life behavior versus durability, even at the molecular level” [15].

Tightening Frames to Reduce Tensions

Many chemists expressed the hope that tensions could be eased by introducing greater rigor into the conduct and evaluation of green chemistry. Central to this response was an implicit assumption that a normalizing frame, and its associated “normal science” approach of objective evaluation and quantitative analysis of tradeoffs, enabled fulfillment of goals in line with the other frames. According to these chemists, the rigor associated with a normalizing frame and with chemists as innovators also could be applied to pragmatic solutions and morally-motivated approaches. One chemist echoed others in observing that some claims to green chemistry involved “improv[ing] in one area and [getting] worse in three or four [other areas]” [2], thus undermining morally-aligned intentions to improve the impact of chemicals. Another noted that “The community is starting to turn to [these chemists] …and say, ‘[You] need to go one step further’” [7]. In other words, for these chemists, the key to addressing tensions was to rely on the tools of “normal science” to evaluate how chemists as innovators were using green chemistry. They also spoke of how chemists in their roles as educators could and should present green chemistry as rigorous science to underpin its claims. One chemist echoed others when he said:

> I tell [students] that [green chemistry] is [about] comparison, … trying to decide which [chemical process] does less damage to the environment. [Green chemistry] is the decision making process, or the research that goes in to [that]. I wish it was called “green-er chemistry” because green chemistry implies it’s an absolute … thing. There is no process out there that we can ever invent that will do no damage [33].

Beyond foregrounding the normalizing frame and, by association, rigorous science, these chemists urged the use of metrics and tools to evaluate green chemistry. Most popular was Life

Cycle Analysis[5] (LCA). One chemist said "LCA is a more holistic tool to look at a range of impacts" [2]. Another noted LCA's value in supporting chemists in their roles as communicators:

> It's not enough to say, "We have designed this new product according to [green chemistry] principles three, four, and five." … If you really want to convince your consumers or government … you have to measure that quantitatively … [So], incorporating a tool like LCA allows [us] to measure the actual greenness [31].

In sum, experiencing frame incompatibility and associated tensions within green chemistry led some advocates to seek to ease tensions by subsuming other frames within the normalizing frame, thus tightening the framing of the change effort in hopes of advancing a more rigorous approach to green chemistry.

Sustaining Versatile Framing to Further the Change

At the same time, other chemists worked to sustain the versatile framing that enabled growth through role-centric mobilization, foregrounding the validity of a change effort without a cohesive thrust even as they recognized the resultant tensions. For example, when asked about the state of green chemistry in 2015, one informant reflected:

> Is it cohesive ?... I don't know that … cohesion is a virtue. I think agility and resilience is a virtue. I think innovation and dynamism is a virtue. I think that alignment along certain foundations is a virtue [32].

Many others shared the sense that green chemistry benefited from the variety of activities chemists performed under its banner. One said, "To me, the great thing about green chemistry is I don't quite know what will happen tomorrow. It changes every day" [25]. An editorial article published in 2013 asserted that the lack of cohesion stemmed not just from chemists' actions, but also from the broader context in which they acted:

> Green chemistry can still take different forms and pathways… It is not inevitable that one form will dominate; multiple strands may coexist. … Many chemists … presume that green chemistry has its own intrinsic trajectory and definition, rather than

[5] Life cycle analysis evaluates the environmental impacts of a process or product across its entire lifecycle (from raw material extraction to disposal), and across a variety of impact areas (e.g. toxicity, greenhouse gas emissions, energy consumption, water consumption).

> acknowledging that other societal actors may have their own visions and narratives of what green chemistry means. (Iles, 2013: 466)

This response acknowledged that chemists with diverse specialties and situated in diverse contexts applied the green chemistry principles in ways that were attuned to their specific circumstances. For example, in contrast to a significant focus in the U.S. on research and education, one chemist said, "in Brazil, [and] China and India … green chemistry [is focused] a lot more on improved manufacturing …[which] reflects the cultures and the industrial systems that they come from" [15].

Proponents of this view warned against becoming wedded to tools and metrics for evaluating green chemistry. One said:

> One of the best things that green chemistry can do is remember that we're from a revolutionary spirit and it's good to have these kind of tumults ... Because if we start saying "The only measure of progress is this metric" … [then we've] done a disservice to whatever brilliance our community has been able to achieve [32].

Others asserted that green chemistry principles needed to begin to be seen as an integrated system, and decried efforts to apply simple metrics. One editorial explained:

> Green chemistry is highly contextual, and thus open to a great deal of debate. … A careful reading of the Twelve Principles reveals that green chemistry is a process for thinking about chemistry from a systems perspective, as opposed to set of goals or standards of what makes something green. (Matus et al., 2012: 10896)

Advocates who adhered to this perspective worked to sustain variation by admitting to and accepting the various ways people interpreted green chemistry. As one explained, "a lot of people are getting to [the point where] 'you state what you think [green chemistry] is, I state what I think it is, and we'll talk about the common ground between them'" [14]. Another chemist, echoing others, asserted that pluralism should not be surprising and, furthermore, that an effort to change how chemists thought about and did their work *should* unfold differently from change originating in "normal science":

> [It] is interesting to see differences and I hope, as a community, [we] then ask ourselves, "Maybe we don't need to be so worried about what is or is not green chemistry?" Because clearly, this is a culturally rather than scientifically defined concept [15].

The perspectives and actions of those who encourage sustaining versatile framing suggest that the tensions manifest in the change towards green chemistry may be enduring rather than transitory. Indeed, for a change effort initiated from within a diverse occupation, the urge to sustain multiple frames is not simply a recruiting tool that enables mobilization as a change effort is getting underway; rather, sustaining multiple frames may be a necessary condition when the problems being tackled are inherently complex and preclude straightforward solutions.

A Model of Peer-Driven Occupational Change

We summarize our main findings, which point toward a general model of how members of an occupation can initiate and sustain an effort to change how their peers think about and do their work, using Figure 1. We found, first, as shown in the bottom layer of the figure, that change advocates can instigate a change in the absence of a discrete external trigger through *versatile framing* of the change opportunity. Versatile framing leverages common knowledge shared by occupational members, yet advances distinct frames that couch the appeal of the change in terms of different underlying motivations.

--------------------- Insert Figure 1 about here ---------------------

As shown in the middle layer of Figure 1, versatile framing enables *role-centric mobilization*, because distinct frames resonate with different roles performed by occupational members. In the case of green chemistry, advocates discovered, and then exploited, the resonance of certain frames with certain roles, leading them to tailor their messages to frame the change for specific audiences. In other settings, multiple frames could resonate with a single role, or a single frame could appeal to those fulfilling multiple roles, meaning that role-centric mobilization could lead to more complex juxtapositions of frames and roles. In any case, our findings suggest that change efforts find resonance with occupational members through the roles they fulfill, rather than through the mere fact of their occupational membership.

Role-centric mobilization reflects the heterogeneity within an occupation, suggesting that mobilization for change is enabled by role differences. However, such differences also give rise *tensions* within and among change adherents, which arise from *experiencing frame incompatibilities*. There are distinct loci for these tensions: i) within an individual change adherent as she or he navigates frame incompatibilities in performing multiple occupational roles; ii) between change adherents as they perform and prioritize different occupational roles, and; iii) among occupational members who are dissuaded from adopting the change because they are put off by frame incompatibilities. We depict these tensions with the horizontal arrow in Figure 1.

Finally, experiencing frame incompatibilities led in our case to two divergent responses by advocates. Some advocates sought to *tighten* the frames, subsuming others within a dominant one, in order to reduce tensions. Other advocates actively *sustained versatile framing* to promote the change and its diverse appeals to the different roles chemists played and the situations in which they played them. We depict each response in the third layer of our model.

Overall, the nature of the peer-driven occupational change effort we analyzed is distinct from other accounts of occupational change. In the absence of an external trigger, which can mobilize occupational members against a common enemy, or through a shared identity or history, generating and sustaining versatile frames that resonate with diverse roles is central to the emergence and vitality of a peer-driven change effort, even as they forestall its coherence and closure.

Discussion

We set out to investigate how members of an occupation initiate and sustain an effort to change how their peers think about and do their work. Prior work on occupational change focuses on change that responds to direct external triggers, like technological shifts (e.g., Barley, 1986; Bailey, Leonardi, and Barley, 2012; Nelson and Irwin, 2014), bureaucratic and organizational pressures (Adler, Kwon, and Heckscher, 2008; Bechky, 2011; Chreim, Williams, and Hinings, 2007), and encroachment from other occupations (e.g. Abbott, 1988; Ashcraft, 2013; Begun and Lippincott, 1987). In turn, the mechanisms previously adduced are ones that emphasize the commonalities within an occupation, tying members together as they navigate a common collective response to an external threat. By contrast, in the absence of a clear external trigger, we found that change advocates influenced their peers by articulating a versatile framing of the change, which leveraged core common knowledge while incorporating distinct frames. This lead to role-centric mobilization, as the distinct frames each appealed to different roles that occupational members performed, playing to the heterogeneity within an occupation rather than the commonalities. This approach can enable the emergence of a pluralistic change effort. Yet at the same time, it can surface tensions among the frames, preventing the cohesion of the very changes it enables. The "end state" of such a dynamic is less a settlement of differences that results in the adoption of a cohesive change, and more an ongoing "stable condition of pluralism" (Jones et al., 2012: 1540) – an important but understudied (Greenwood et al., 2011) state that lends itself to ongoing generativity rather than cohesive stasis.

In the subsections that follow, we elaborate on the theoretical implications of these findings, along with the boundary conditions that may limit their transferability. Specifically, we discuss the importance of attending to heterogeneity within an occupation as an enabler of change. Next, we discuss how a pluralistic framing of change can be sustained over time and the "double-edged sword" character of such efforts. Finally, we illuminate how moralizing can both help and hinder change efforts that seek to exploit occupational expertise for the common good.

Occupational Heterogeneity and Occupational Change

Scholars of occupations have tended to focus on the "ties that bind" – the "common tasks, work schedules, job training, peer relations, career patterns [and] symbols" that occupation members share (Van Maanen and Barley, 1984: 291). In turn, research has shown how such commonalities can be leveraged when occupational members need to respond or adapt to external triggers for change, such as shifts in regulation, technology, or jurisdictional boundaries (Bechky, 2011; Goodrick and Reay, 2010; 2011; Greenwood, Suddaby and Hinings, 2002; Nelson and Irwin, 2014). By contrast, our study shows that a key element in *peer*-driven occupational change can be heterogeneity rather than commonality. As our investigation of chemists highlights, although occupation members share an understanding of core practices and principles, the occupation also admits considerable heterogeneity as occupation members fill varied roles, including those of innovator, educator, and problem solver. Many other occupations are similarly characterized by such heterogeneity, including professors (e.g., in their roles as teachers versus researchers), doctors (e.g., in their roles as administrators versus caregivers), and professional musicians (e.g., in their roles as performers versus celebrities).

Other scholars, too, have recognized heterogeneity within occupations and professions. Greenwood and colleagues (2002: 62), for example, write, "Professions are not necessarily homogeneous communities … Decision making within a profession can thus be a political process … in which the competing interests of subcommunities are reconciled and subjugated on an on-going basis." Similarly, Van Maanen and Barley (1984: 318) write:

> There is a continuous process of occupational differentiation within all professions. At any given time, wide discrepancies of status and rewards exist such that any one

> profession (even with its institutional support systems, its self-administered code of ethics, and its professional schools and associations) is a mix of many … occupational communities.

Yet whereas these scholars turn attention to professional associations and other institutions that can serve to bridge and reconcile this heterogeneity, our study instead connects the existence and maintenance of heterogeneity within an occupation to a key mechanism for peer-driven occupational change – the recognition of resonance with, and explicit tailoring of, a change message to the specific interests of narrower occupational roles.

Our research thus responds to calls to study change in settings where there is a "diversity of membership" (Greenwood, Suddaby, and Hinings, 2002: 74) and it suggests that heterogeneity within an occupation may not only serve as a source of friction or competition, as other studies note, but also as a supportive condition for enabling occupations to change. In turn, our work suggests that future research might explore both the costs and benefits of intra-occupational heterogeneity along with the ways in which the degree and type of heterogeneity shapes other important occupational processes. It is also important to recognize that occupational roles are not stable entities, but are potentially "loosely and dynamically structured" (Okhuysen and Bechky, 2009) because roles are socially negotiated and reflect others' expectations of a given role performance (Mantere, 2008). Future research could explore role diversity in greater depth, using ethnographic data, for example, to trace occupational members' actual performances of roles and how this might reflect or open opportunities for role-centric mobilization.

One important influence on how occupational heterogeneity might facilitate change is the degree of professionalization of the occupation. In professionalized occupations, there may be strong accrediting bodies or professional associations that tie together otherwise diverse occupation members (Greenwood et al., 2002; Van Maanen and Barley, 1984). Accordingly, there may also be more stringent and stable role expectations, that are less subject to negotiation by those who perform them. In such cases, a versatile framing of peer-driven change may be less feasible and less successful, because advocates would have limited ability to leverage occupational heterogeneity. In our case, the relatively peripheral role played by the American Chemical Society (ACS), the dominant association for the occupation of chemists, was likely an enabler of the peer-driven change we observed. While the ACS aided the move towards green chemistry by supporting an annual conference and absorbing the independently-founded Green Chemistry Institute in 2001, it also avoided moves towards green chemistry accreditations and other certifications. Had the ACS played a more central coordinating and driving role, it, perhaps ironically, may have suppressed the diversity of actions and motives that fed the growth of green chemistry.

Another key source of heterogeneity, and one that may shape occupational change efforts regardless of the degree of an occupation's professionalization, is the "newcomer." Reay and colleagues (2006: 977) write, "Newcomers to a field … are relatively unembedded in their context and therefore capable of acting in ways contrary to the established patterns and norms." Perhaps more so than in organizational settings, occupations are continuously absorbing newcomers who represent new generations of specialists trained in the occupation's core knowledge and practices, yet who have not fully grasped the nuanced and tacit aspects of their roles (Ibarra, 1999; Pratt et al. 2006). In fact, newcomers may harbor idealistic notions about how they will act in an occupational role, even as they recognize they do not fully understand the role (Ibarra, 1999). As the same time, newcomers work to learn and internalize an occupation's roles, patterns and norms (Ibarra, 1999; Pratt et al. 2006; Leonardi et al., 2009). For example, Leonardi and colleagues (2009) study how students become socialized into the engineering profession, transitioning from "outside perceptions" of the profession to an internalization of practitioners' perceptions. Our study affirms that newcomers' "fresh eyes" and their attempts to learn an occupation work simultaneously to shape their experience of the occupation (Ibarra, 1999; Pratt et al., 2006), but also suggests that newcomers influence the way occupational incumbents perform their own roles. Thus, newcomers (chemistry students in our setting), who represented a demographic cohort interested in "doing good" and practicing "responsible" chemistry, served to demonstrate to incumbent chemists the value of adopting green chemistry in their educational roles. At the same time, students, as they entered jobs as junior faculty members or industry chemists, served as carriers of the moralizing frame for occupational change as they became more embedded in the occupation. Future research could explicitly focus on how newcomers influence the occupational heterogeneity that enables peer-driven change.

Finally, it may be that differences within an occupation can be leveraged even when change is externally triggered rather than peer driven. For example, Kellogg (2009) describes how surgeons struggled with new regulations on shift length, and details how people in different positions in an organization (e.g., staff surgeons, interns) approached the change. Our analysis suggests that appealing to the different roles that surgeons may play (e.g., as healthcare providers versus educators) also could facilitate change.[6]

Sustained Pluralism and Occupational Change

Beyond the importance of leveraging occupational heterogeneity to initiate peer-driven change, our findings also suggest that a key to such change lies in sustaining this pluralism. Previous work on how diversity enables change emphasizes how diverse perspectives are brought together to initiate a change. For example, Gioia, Nag, and Corley (2012: 365) discuss the benefits of "visionary ambiguity," whereby change may be best initiated when the approach

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[6] We thank an anonymous reviewer for raising this point.

is "more imprecise, equivocal, and malleable." Yet Gioia and colleagues (2012) also argue that ambiguity should be reduced over time in order to foster change implementation. Similarly, scholars find that organizational change can be instigated by recognizing and leveraging people's differences (Meyerson and Scully, 1995; Dutton et al., 2001; Kellogg, 2011), but again, that strategies ultimately aim to build consensus around the rationale for change (Bansal, 2003; Howard-Grenville, 2007).

By contrast, in an occupational setting and absent an external trigger for change, it is less likely and may well be less desirable that a convergent frame or a new shared oppositional identity (Kellogg, 2009) will emerge. Convergence is less likely because occupational members share fewer opportunities for co-location than do members of an organization, and there may be fewer coordinating mechanisms. Furthermore, convergence is undesirable if the growth and appeal of the change effort relies on its diverse appeal to occupational members who perform different roles. As we found, sustaining pluralism was important to many change advocates. Indeed, many green chemistry advocates actively resisted attempts to "circle the wagons prematurely" [1] as they worked to sustain the diverse frames that had proven effective in initiating the change. In this way, our findings more closely mirror Meyer's (1984) discussion of organizational decisions. In an organizational setting, Meyer (1984: 15) proposes that "Ambiguous language supplies the lubricant that helps mesh organizational subcultures invoking different metaphors and espousing discordant ideologies." and that "Linguistic equivocality and abstraction [can] increase as choice processes unfold."

By showing how wide diffusion can occur despite a lack of closure or a lack of reduction in pluralism, our work also complements that of Ansari, Fiss, and Zajac (2010), who argue that practices, far from remaining homogeneous, change as they diffuse, leading to increased heterogeneity and adaptation. Yet whereas Ansari and colleagues (2010) focus on more typical cases in which diffused practices are initially bounded and coherent, our findings push the case for heterogeneity further by highlighting how diffusion can proceed even when – in fact, *because* – the *initial* practices associated with a change effort are intentionally diverse. This is a very different starting condition from many studies of change or diffusion, which focus, respectively, on a defined end-state or a discrete innovation, even if they find ambiguity in the initial framing or unfolding of the change. Future research can probe further the conditions under which a change effort launched with the versatile framing of broad, aspirational goals is enabled over time by sustaining pluralism.

Of course, sustaining pluralism is not without costs. Rather, multiple frames present a double-edged sword when they are leveraged simultaneously – which is more likely when advocates lack the mobilizing and focusing effect of external triggers for change. On the one hand, the use of distinct frames appeals to occupational peers in the diverse roles they play, broadening the potential appeal of the change effort. Yet on the other hand, the activation and deployment of several frames simultaneously heightens the likelihood that incompatibilities are revealed among them, creating tensions within and beyond the change movement.

This phenomenon is likely to be seen in other occupational settings. In many occupations, members perform multiple roles, moving among them as situations or settings demand. With such roles come potentially distinct understandings of work, priorities, values, and commitments (Leavitt et al., 2012; Wright et al., 2016). These understandings will shape how multiple frames are received and the potential tensions that arise from their incompatibilities. For example, efforts to change care processes in the healthcare professions and in hospitals often reveal tensions among normative commitments (e.g., doing innovative science, exercising professional discretion for individual cases), moral commitments (e.g., do no harm, patient centered care), and pragmatic commitments (e.g., expand access cost effectively) (Dunn and Jones, 2010; Nigam, 2012). Future research might continue to explore the extent to which sustaining versatile framing of a change is not simply a necessary response to occupational heterogeneity, but also a potential source of generativity and vitality in a change effort, as many green chemistry advocates maintained.

Moralization and Peer-Directed Change

Finally, our work raises important implications for understanding how moral frames can promote or inhibit occupational change, including that aimed at how members address "grand challenges," or complex, unsolved problems of importance to human, ecological, and societal wellbeing (Ferraro, Etzion, and Gehman, 2015; Howard-Grenville, Buckle, Hoskins, and George, 2014). Chemical pollution, of course, is a grand challenge and green chemistry can be part of the solution. Chemists, and members of many other occupations have specialized expertise – like knowledge of chemical synthesis, climate modeling, or healthcare provision – that makes them uniquely qualified to act on important societal issues (Maguire and Hardy, 2009; Lefsrud and Meyer, 2012; Nigam, 2013). As one chemist, reflecting on the need to mitigate the impacts of chemicals on human and environmental health, asked, "If chemists don't do it, who is going to?" [29].

As both scholars and practitioners pay increasing attention to grand challenges, our work suggests that it is critical to consider how occupational features shape the capacity for occupational members to mobilize for and act on these challenges. Specifically, our work shows that the way in which occupation members' expertise is tapped and whether the impetus is internal or external matters enormously. Indeed, the same chemist quoted above, who suggests a unique role for chemists in solving key environmental problems, also offered the statement from our opening section: "the only objection to green chemistry is from within chemistry" [29].

Our analysis offers several explanations for this conundrum, in which the very people who may be best-equipped to tackle grand challenges are also most likely to resist the changes to occupational practices and commitments needed to do so. First, the tension of complexity revealed that occupational members have an inherently nuanced understanding of the knowledge and practices that underpin their occupation. They recognize the subtleties and tradeoffs involved in applying and extending this knowledge and practice, and they regard morally-tinged calls for change that appeal to non-specialists (e.g., calls for "nontoxic chemicals" or perfectly benign production) as technically and scientifically naïve. This specialist understanding suggests that attempts by outsiders (e.g., non-members of the occupation) to motivate change may be met with the simple objection that "they just don't understand."

Thus, despite the far-reaching societal implications of grand challenges such as chemical pollution, our analysis suggests that moralized calls for change may be more effective when they come from *within* rather than outside the occupation. Indeed, as Leavitt and colleagues (2012: 1317) note, membership in an occupation offers "particularly influential sources of moral prescriptions," suggesting that peer-driven change may be a particularly potent mechanism for urging occupational members to address societal issues. Accordingly, our analysis highlights appeals to morality as one key frame by which occupational change can be motivated. It also suggests that this mechanism is effective, in part, because occupational members cannot dismiss moral claims by responding that their advocate peers "just don't understand"; by definition, as occupational insiders themselves, they *do* understand. Moreover, occupation members often put great weight on their peers' impressions and seek to uphold values when they are undermined (Wright et al., 2016). Thus, a peer's moralizing can hit close to home and can motivate change.

Such efforts, however, also can be problematic, as the case of green chemistry highlights. First, moralizing can give rise to fears of judging others and being judged by others, and can threaten group cohesion (Kreps and Monin, 2011; Minson and Monin, 2012). As noted, work on external triggers for occupational change shows how a common outside "enemy" can elicit a common basis for action by occupation members (e.g., Bechky, 2011; Goodrick and Reay, 2011; Starr, 1982). Yet if occupational change is initiated by peers' calls to "do good," the "enemy" may be in the next cubicle or at the neighboring lab bench and the response can elicit divisiveness rather than common ground – even, ironically, as the change is presented as being in the occupations' service of the common good. Recall the green chemistry advocate who expressed others' concerns by saying, "You're deliberately making a lot of people's work unacceptable" [25]. Thus, while moralization can be one path by which advocates advance internally-driven change, it may backfire for some members of the occupation who feel threatened by their peer's judgements, even if these judgements are more imagined than real. Consider a parallel concern expressed by some adherents of Positive Organizational Scholarship (POS), who, according to one, perceive that their peers resist POS because it might imply other organizational scholarship is "negative." This also suggests that moralizing will be ineffective at initiating peer-driven organizational change if it is the only frame presented.

Second, moralizing also can be problematic in so far as it conflicts with claimed objectivity. Many occupations – including medicine, jurisprudence and journalism – claim impartiality and objectivity as core values. Attempts to change work practices on moral grounds might be taken by some as assaults upon the objectivity of an occupation or profession. Indeed, by offering alternatives that also cast light on the existing or presumed moral prescriptions of a given occupation, moralizing frames highlight that work practices and products are *not* value neutral but rather laden with moral implications and subjective interpretations. In our case, the response to tensions of reconciling frames – by subsuming them under a normalizing one that asserted the primacy of "sound science" in shaping determinations of environmental impact and practical application of green chemistry – reflected an effort to reassert a familiar normative commitment of chemists as objective scientists. While our study suggests that moralization may be especially challenging in seemingly objective occupations, the sustained pluralism and dynamism of the current state of green chemistry suggests that including such appeals in a broader change effort is not impossible. Indeed, by calling on occupation members to reflect on the moral underpinnings of their work, change advocates might initiate a more thoughtful and individually-sustained trajectory of change than might be seen if an external trigger demanded a response, or if a centralized body pushed for a uniform internally-directed change.

Boundary Conditions and Future Research Opportunities

Our theorizing is subject to several boundary conditions. First, we consider a change effort launched within a scientific occupation, where change may be especially difficult. Bourdieu (1999) argues that since members of a scientific field are the only ones who can evaluate each other's work, they may play a more conservative role in policing their occupation than members of other occupations. Thus, some of the processes and tensions that we observed may be more transparent in a setting like chemistry.

Second, our analysis does not focus on how the specific organizational environments within which our interviewees work may have shaped their approaches to change. Yet clearly organizational and occupational lenses influence one another (Anteby, 2008; Covalevski et al., 1998; Fine, 1996; Hughes, 1971). For example, Kunda (1992) shows how engineers' identities can be reinforced by both their employer and their fellow occupation members. Conversely, Van Maanen and Barley (1984) observe that there may be situations in which "what is deviant organizationally may be occupationally correct (and vice-versa)." Although our study offers attention to broad organization types (e.g., universities versus firms), future work might consider how specific organization environments and features of an occupation interact to shape change.

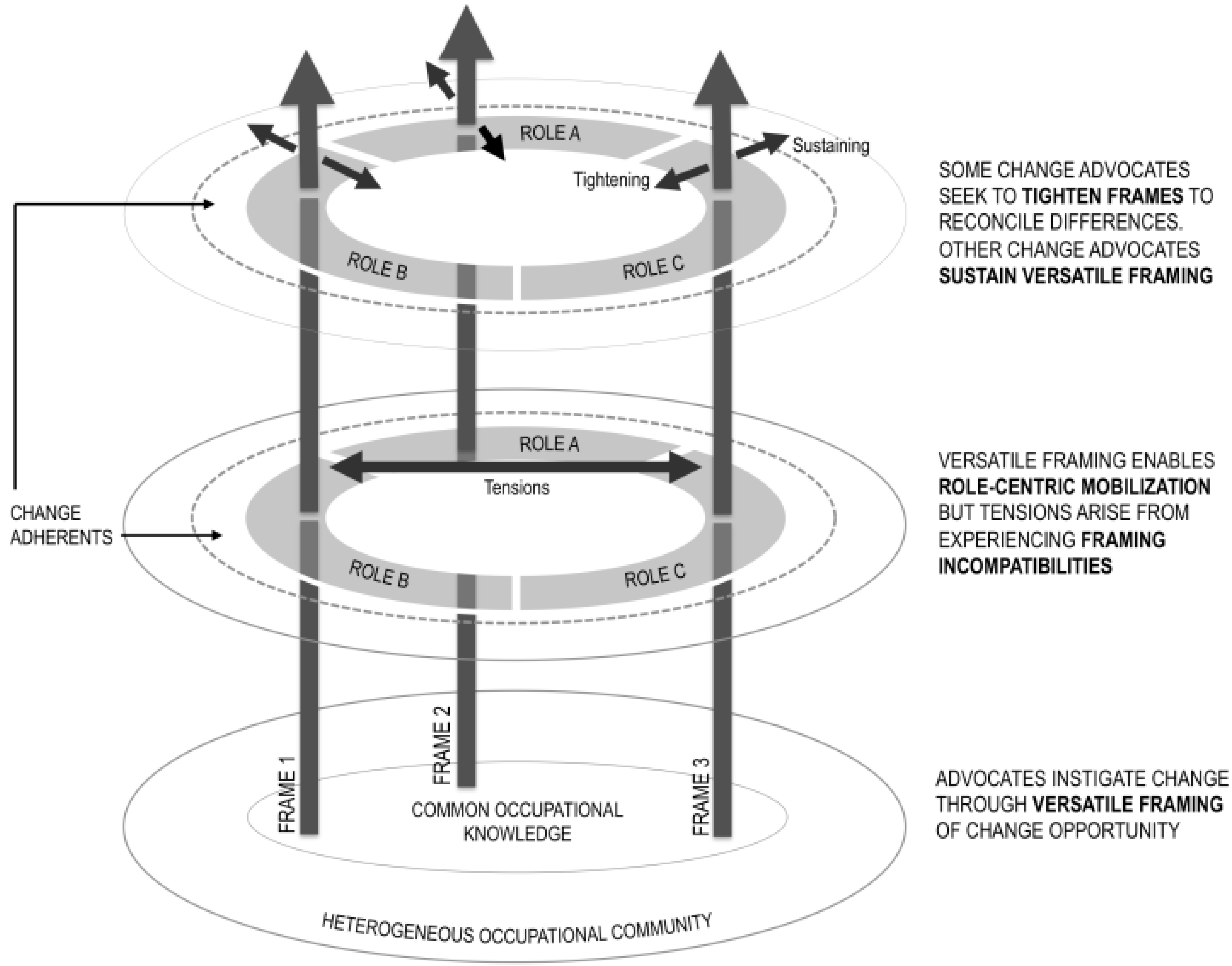
Finally, our study must be placed within the broader context of the emergence of the environmental movement. This movement had significant traction prior to the time period we investigate, as evidenced in the United States by the publication of Rachel Carson's *Silent Spring* (1962), the establishment of the Environmental Protection Agency in 1970, and the passage of the Clean Air Act (1970), the Clean Water Act (1972), and the Pollution Prevention Act (1990). Nonetheless, concern for environmental sustainability undoubtedly grew over the period that we witness. Our study provides insight into how attempts at occupational change may, in fact, leverage such broader social shifts, even as it cautions against automatically interpreting such shifts as catalytic. (Indeed, if societal shifts were the immediate cause, we might have expected green chemistry to emerge in the 1970s, with the advent of the environmental movement and regulatory protections, rather than the 1990s.)

In closing, our analysis of the emergence and evolution of green chemistry highlights how occupation members can promote a change in how their peers think about and do their work. The nature of and mechanisms driving such change, however, differ significantly from occupational change resulting from external triggers. Because occupational experts have such a hold on the practices that shape the health of our planet and our human societies, it is particularly important to extend our understanding of the vital processes through which such experts seek to transform their ways of working. Our study uncovers how these efforts take advantage of, but also suffer from, heterogeneity within occupations and spawn vibrant, if tumultuous, change efforts.

TABLE 1: Description of Data

Data Types (Dates)	Amount or Location	Use in Analysis
Primary Data		
Interviews		
24 Semi-structured interviews, lasting between 25 minutes and 2 hours (Conducted in 2009 and 2010)	About 340 single-spaced transcript pages	Provided insight into individuals' personal involvement with green chemistry, their perceptions of its growth and evolution, their sense of opportunities and barriers to growth, and how they and others used the label "green chemistry"
12 Semi-structured interviews, lasting about 30 minutes each (Conducted in 2013)	About 93 single-spaced transcript pages	Provided insight into how individuals used the practices of green chemistry, how they thought about themselves as chemists, and their understanding of resistance to green chemistry within the field of chemistry
10 Semi-structured interviews, lasting between 30 and 60 minutes (Conducted in 2015)	About 149 single-spaced transcript pages	Provided insight into skeptics' general impressions of green chemistry and reasons for associating (or not) with green chemistry
Naturalistic Observation		
Green Chemistry and Engineering Conferences and Presidential Green Chemistry Awards presentations (4 total between 2010 and 2012)	Washington, DC	Enriched our understanding of the field, exposed us to key issues and debates, provided sensitization to identity tensions and work, highlighted valued players and developments
Green chemistry workshops (4 total between 2009 and 2011)	Eugene, OR, Montreal, QC (2), and Berkeley, CA	Enriched our understanding of diverse aspects of green chemistry policy, educational initiatives, and research. Exposed key players' perspectives on the opportunities and challenges facing green chemistry
Secondary Data		
Editorials and Commentaries		
Multiple Commercial Databases (1996 through 2015)	84 Editorials and Commentaries	Validated interview findings and contributed additional context and perspective
Publication Data		
SciFinder Scholar-Derived Database (1990 through 2008)	6,394 Peer-Reviewed Publications	Captured size, diversity and growth of the field. Identified interviewees
Archival Data		
Books, scholarly articles, dissertations	About 10	Established chronology of field

FIGURE 1: A Process Model of Peer-Driven Occupational Change



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Appendix A: 12 Principles of Green Chemistry

1. Prevent waste: Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.

2. Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.

3. Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.

4. Design safer chemicals and products: Design chemical products that are fully effective yet have little or no toxicity.

5. Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.

6. Increase energy efficiency: Run chemical reactions at room temperature and pressure whenever possible.

7. Use renewable feedstocks: Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.

8. Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

9. Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.

10. Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.

11. Analyze in real time to prevent pollution: Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

12. Minimize the potential for accidents: Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Source: Anastas and Warner, 2000

Appendix B: Interview Guide for First-Wave Interviews

Interviewee's position and experience in the field

1. First, can you tell me a little bit about your *current* involvement in green chemistry?
2. What led you to this role? (It may help to have the person sketch, and provide, a personal timeline of their involvement).
3. How did you first become interested in working in the area of green chemistry?
4. If you had to define green chemistry to a lay person, how would you do so?

Interviewee's perspective on the history and unfolding of the field
We are interested in understanding the early days of green chemistry, and how things have evolved. The next several questions consider these issues.

5. Are you aware of the early days of green chemistry? If so, can you describe the key events, publication, meetings, etc. and their timing?
Follow up: What was the significance of each of these? (events, publications, meetings, etc.)?
6. What do you think contributed to the growing interest in (or acceptance of) green chemistry?
7. Were there any barriers to growing the field of green chemistry? If so, what were these, when, and why did they occur?

Current state of the field and follow on interviews

8. What are the current opportunities, or challenges, to the further growth (in interest in or acceptance of) green chemistry? (Probe: what will it take to overcome these?)
9. Is there anything important about the emergence and growth/development of green chemistry that we haven't touched on? Is there anything you would like to add?
10. Are there any other individuals that you feel we should speak with to gain further perspective on green chemistry?

Appendix C: Interview Guide for Second and Third-Wave Interviews

Second-Wave Interview Questions

1. Do you incorporate green chemistry into your day-to-day work? If so, how? Please offer a few examples. If not, why not?

2. In what ways, if any, does green chemistry fit with how you understand or think of yourself as a chemist? (e.g., Does green chemistry alter how you think about and/or practice chemistry?) Please explain.

3. Why do you think some people (perhaps including yourself) do not embrace green chemistry and/or do not think of themselves as green chemists?

Third-Wave Interview Questions

1. Please briefly describe your awareness of green chemistry. When did you first hear of it? What do you make of it?

2. Do you consider yourself part of a green chemistry community? What are the main reasons for you practicing/not practicing green chemistry?

3. [If do not ascribe to green chemistry/not consider part of community]. What are the reasons for your choosing not to practice green chemistry, or for choosing not to affiliate with the green chemistry community?

4. What does "green chemistry community" mean to you? How would you describe the state or nature of this community today?

[Are you aware of others who share your views on green chemistry, or do they differ, and, if so, how?]

5. What are the main opportunities *and* challenges to advancing green chemistry (feel free to think broadly, to include chemistry education, research, industry etc.)

6. Do you have anything else to add, or any questions for me/us?

Thank you very much for your time.