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Optimism, Innovativeness, and Competitiveness: The Relationship between Entrepreneurial Orientations and the Development of Science Identity in Scientists

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Abstract

We contend that the work scientists do is entrepreneurial because they are in the business of discovering, evaluating, and exploiting opportunities to create new knowledge. In this article, we examine the relationship between Science, Technology, Engineering, and Mathematics (STEM) scholars' holdings of traits associated with entrepreneurial activity and the degree to which these scientists consider being a scientist important to their sense of self. In particular, we argue that optimism, an innovative mindset, and competitiveness should be associated, positively, with STEM scholars' science identity. Our results, based on a survey of 215 postdoctoral trainees in STEM disciplines, show that the more academic scientists have of each entrepreneurial disposition, the greater their science identity centrality.

Keywords

higher education, STEM identity, academic entrepreneurship, optimism, innovation, competition

Social scientists engaged in efforts to understand both commitment to and attrition from research careers—particularly those as science faculty—have long recognized that trainees' understandings of themselves—their self-concept—is an important component of career development. One of the strongest predictors of commitment to Science, Technology, Engineering, and Mathematics (STEM) research careers is one's sense of themselves as a scientist or engineer, or *science identity* (Carlone and Johnson 2007; Chemers et al. 2011; Stets et al. 2017). Most studies of science identity have focused on programmatic interventions—such as enhanced interactions with science mentors and STEM enrichment programs—as key contributors to a heightened sense of one's self as a scientist, especially for underrepresented minorities and women (Bakken et al. 2010; Carlone and Johnson 2007; Chemers et al. 2011; Fleming et al. 2013; Hudson et al. 2018; Jackson and Suizzo 2015; McGee et al. 2016). This focus on the influence of exposure to scientists and science

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tasks has been a valuable starting point for these investigations into this important micro-level characteristic. This article looks more broadly at science culture to determine if there are other attributes of science research environments—attributes not explicitly related to science—that may also be associated with increases in science identity. We argue that cultural attributes associated with entrepreneurship are a useful launching pad for such an investigation.

Shane and Venkataraman (2000) define the essential elements of entrepreneurship as "sources of opportunities; processes of discovery, evaluation, and exploitation of opportunities; and the set of individuals who discover, evaluate, and exploit them." We contend that the work academic scientists do is entrepreneurial—and, therefore, worth studying as such—because they are in the business of discovering, evaluating, and exploiting opportunities to create new knowledge. Historically, most research on entrepreneurship engaged in by academic scientists suggests this link to entrepreneurship because those scientists were engaged in the exploitation and production of knowledge for economic value (Colyvas and Powell 2007; Goethner et al. 2011; Mosey and Wright 2007).

We argue that most research activity engaged in by academic scientists is entrepreneurial in nature, even when there is no financial benefit or motivator for its execution. In this way, academic entrepreneurs are similar to other classes of entrepreneur (e.g., social entrepreneurs, political entrepreneurs) who share similar entrepreneurial mindsets as economic entrepreneurs—that is, to discover, evaluate, and exploit opportunities—but are not driven by a profit motive (Boettke and Coyne 2009). There are a number of traits considered important for entrepreneurial behavior. Three seem particularly appropriate when considering academic entrepreneurship: dispositional optimism (Scheir, Carver, and Bridges 1994), innovativeness (Hmieleski and Corbett 2006), and competitiveness (Lumpkin and Dess 1996).

In this article, we examine the relationship between postdoctoral scholars' holdings of traits associated with entrepreneurial activity and the degree to which these scientists consider being a scientist important to their sense of self. In particular, we argue that optimism, an innovative mindset, and competitiveness should be associated, positively, with STEM scholars' science identity. The article is structured as follows. First, we describe science identity and review main factors the literature suggests are associated with it. Next, we explain how entrepreneurship, and particularly academic entrepreneurship, is a useful framework for understanding the work and identity of academic scientists. We then present an analysis of current postdoctoral trainees in STEM disciplines that shows that entrepreneurial orientations are significant predictors of STEM scholars' science identity. Finally, we discuss our findings' implications for theory, future research, and the professional development of STEM scholars.

Background

Science Identity Centrality

Retention of students, particularly racial minorities and women, in STEM disciplines and STEM careers has been a long-standing national concern (Stets et al. 2017; Vincent-Ruz and Schunn 2018). Social scientists have been committed to understanding the factors that predict both attrition from and commitment to science careers. Research on STEM career exploration and development has highlighted *science identity*, and particularly *science identity centrality*, as an important factor in predicting commitment to science-related fields (Merolla and Serpe 2013; Stets et al. 2017; Vincent-Ruz and Schunn 2018; Xie, Fang, and Shauman 2015).

An identity is a set of meanings that are ascribed to an individual based on particular characteristics, roles, and social memberships (Burke and Stets 2009; Stets et al. 2017). Fundamental to the concept of identity is the personal appropriation of these meanings by individuals, an appropriation that moves beyond simply understanding that others might see them through these lenses, but incorporating those meanings into their understanding of themselves, their self-concept.

Individuals possess at least three kinds of identities: social identities, role identities, and personal identities. Two of these—social identities and role identities—are institutional in that their meaning mostly comes as a result of the individual's social relationships. Specifically, social identities are developed through membership in categories (e.g., race, gender, profession) and role identities are a function of one's position (role) relative to someone else (e.g., child and parent, student, and teacher). The other, personal identity, is more unique to the individual, in that it is shaped by both similarities to and differences from other people who might hold similar social and role identities. Personal identities often have a descriptive dimension, for example, "good mother" or "incompetent scientist."

All three kinds of identity are social constructions shaped and reinforced through interactions with other people (Burke and Stets 2009). Together, they inform one's sense of themselves as a social actor. For example, two people, both of whom are women students in chemistry classes, may have different impressions of themselves as scientists. One may consider herself a woman "scientist" while the other may simply consider herself a woman "science student." It is this difference that has given rise to the concept, *science* (or more precisely, *scientist*) *identity.* A person is both endowed with and embraces the identity of a scientist based on their holdings of the characteristics conventionally assumed to be held by scientists as a social category. According to social identity theory, these two processes—categorization (i.e., what do scientists do) and identification (i.e., I do what scientists do)—are related cognitive processes that would lead someone to strongly identify as scientists (Tajfel and Turner 1979). Science identity centrality, then, is the degree to which an individual feels that being a scientist is important to their sense of themselves and what kind of person they are.

The meanings ascribed to these identities then serve as guideposts for expectations of what that individual might do; identity and behavior are linked (Burke and Reitzes 1981). Consequently, we would expect a woman who assumes the identity "scientist" would take inventory of her holding of the attributes of a scientist—attributes that give the identity meaning—and will do the kinds of things scientists do, such as pursue careers in science (Stets et al. 2017). The concept has been explored in various ways in recent research, including its relation to science literacy (Brown 2004; Reveles et al. 2004), success in graduate school and STEM careers (Merolla and Serpe 2013; Stets et al. 2017), persistence (Cech et al. 2011; Chang et al. 2011), and how it varies across race and gender (Beyer and Haller 2006; Chinn 2002; Jackson et al. 2015).

In Carlone and Johnson's (2007) examination of science identity centrality, they argued that the development of a strong sense of oneself as a scientist requires both competence in science and recognition of that competence by others. They said, "one cannot pull off being a particular kind of person (enacting a particular identity) unless one makes visible to (*performs for*) others one's *competence* in relevant practices, and, in response, others *recognize* one's performance as credible" (Carlone and Johnson 2007:1190). These two predictors of a strong science identity—competence and recognition—have been further explored through the concepts, *science efficacy* and *positive reflected appraisals* (Stets et al. 2017).

Science efficacy refers to an individual's belief that they are capable and competent enough to produce a particular outcome, specifically in science-related tasks and activities (Chemers et al. 2011; Stets et al. 2017). Individuals who feel that they are able to understand difficult material and master difficult tasks possess a high degree of science efficacy. Researchers have found that science efficacy is acquired through socialization experiences in STEM courses and enrichment programs that provide prospective scientists with authentic opportunities to develop science competence (Artino 2012; Bakken et al. 2010; Chemers et al. 2011; Merolla and Serpe 2013). Science efficacy impacts an individual's perception of themselves, such that an individual who has a high degree of science efficacy will be more likely to strongly identify as a scientist (Vincent-Ruz and Schunn 2018).

Research on science identity has also highlighted the impact of external perceptions and evaluations on an individual's propensity to identify as a scientist (Merolla et al. 2012; Stets et al. 2017). Individuals internalize how people in their environments perceive them and this, in turn, impacts how individuals perceive themselves. The kinds of STEM enrichment programming that support science efficacy also serve to give students exposure to positive appraisals of them as scientists by other scientists. These affirmations of their scientist behaviors strengthen the students' sense of themselves as scientists (Merolla and Serpe 2013; Merolla et al. 2012; Stets et al. 2017).

This pattern—that individual's experiences in science-training environments instills within them a sense that they are scientists—is a function of trainees' exposure to scientific tasks, scientific actors, and scientific culture. Research on science efficacy and science community recognition has shown us the relationship between those factors and science identity centrality. Less research has been done on the cultural attributes of scientific research environments that might be related to heightened science identity centrality. This study seeks to determine if there are such cultural attributes that, once internalized by science trainees, help strengthen their sense that they are (to use Carlone and Johnson's phrasing) "pulling off" being a scientist. Again, in the language of social identity theory, if exposure to science culture aids categorization (i.e., what attributes are common to scientists) and positive identification with that category (i.e., I do what scientists do), it would follow that that person would develop a stronger sense of themselves as a member of that category.

As we will show, at its core, being a scientist—particularly in academic settings—is about marshaling (old and new) resources to create new knowledge and then convincing others to value and then adopt that knowledge. These tasks are similar to those undertaken by another set of social actors: entrepreneurs. We argue that science research is often entrepreneurial and, therefore, the dispositions that underlie the entrepreneurial identity also underlie the identity of scientist.

Academic Research as Entrepreneurial Activity

The classical definition of entrepreneurship as, exclusively, the creation of new business ventures with the expectation of a financial return on investments of time and money has long been replaced by economists and sociologists who study entrepreneurial orientations, opportunities, and outcomes. From Schumpeter's (1911) recognition that all entrepreneurs do not create new businesses to Benz' (2009) recognition that not all entrepreneurs seek financial profits from their entrepreneurial ventures, our understanding of what entrepreneurship is and who entrepreneurs might be has evolved considerably. The changes in the definition have enabled researchers to investigate entrepreneurial actors and activities in contexts we would not expect to find either, such as political campaigns (Sheingate 2003), social service organizations (Mort, Weerawardena, and Carnegie 2003), religious organizations (Christerson and Flory 2017), K-12 education (Hess 2006), and the context we are investigating: research university science departments (Casati and Genet 2014).

We use Shane and Venkataraman's (2000) definition of entrepreneurship as a framework for investigating the relationship between academic science research and entrepreneurship. Shane and Venkataraman (2000) defined the essential elements of entrepreneurship as "sources of opportunities; and processes of discovery, evaluation, and exploitation of opportunities," and entrepreneurs are "the set of individuals who discover, evaluate, and exploit them" (p. 218). In recent years, scholarship has emerged that situates some academic scientists (i.e., tenured and tenure-track faculty in STEM disciplines) as entrepreneurs in that they seek patents for their research and reap material benefits as a result of technology transfer (Colyvas and Powell 2007; Laukkanen 2003; Slaughter and Rhoades 2004). These approaches define academic entrepreneurship (too) narrowly as the commercialization of academic knowledge, production, research, and social processes (Wadhwani et al. 2017). We believe that a broader conceptualization of academic entrepreneurship should be explored. We cannot assume that all academic entrepreneurs are driven by a desire to produce knowledge for financial gain; most are not. In the business world, entrepreneurial intention, or the mindset that drives individuals toward the pursuit of a new enterprises, is not always profit-oriented (Boyd and Vozikis 1994). For many, entrepreneurship is process-oriented and the benefits of engaging in entrepreneurial enterprise may be financial, but are often nonpecuniary (Badelt 1997; Benz 2009; Campbell and Mitchell 2012; Peters, Frehse, and Buhalis 2009; Stewart et al. 1999). We agree with this conceptualization of entrepreneurship and contend that academic entrepreneurs engage in the production of knowledge because of their desires to innovate, discover, and eventually disseminate that knowledge.

There has been some research that examines the link between nonmonetized academic science and entrepreneurship (Mars and Rios-Aguilar 2010; Pilegaard, Moroz, and Neergaard 2010; Sinell, Heidingsfelder, and Schraudner 2015; Ylijoki 2003). That research found similarities between economic entrepreneurs and academic scientists. For example, Etzkowitz (1996, 2003) found that academic scientists and economic entrepreneurs were motivated to produce knowledge by their desire to compete for economic resources to create their products. Another study by Sinell et al. (2015) found that both academic scientists and economic entrepreneurs have a desire to "realize their own ideas." In practice, this means that academic scientists and economic entrepreneurs value having the autonomy to be innovative and creative.

Casati and Genet (2014) defined scientific entrepreneurs as

> scientists with entrepreneurial capabilities, but who work within academia who not only perform research, but are also involved in acquiring resources from different sources (funding agencies, firms, professional associations, etc.), in combining internal and external resources to shape scientific avenues, and in gaining legitimacy for these new avenues by organizing workshops, conference, special issues or setting up new journals, building on their scientific reputation to transfer it to other networks. (P. 24)

Like Casati and Genet, we contend that the work academic scientists, particularly, engage in is entrepreneurial.

Although it is certainly true that bench scientists in academic, industry, and government contexts are also engaged in scientific discovery, we argue that the knowledge production directed by academic scientists (i.e., tenured and tenure-track faculty in STEM disciplines) is more consistently entrepreneurial in the ways Shane and Venkataraman (2000) described. Postdoctoral trainees—even more than undergraduate and graduate trainees—are exposed to this culture and its values and come to believe that a "real scientist" is an entrepreneurial one (Price et al. 2017).

In their analysis of postdoctoral discourse about "bench scientists" and "principal investigators" (i.e., academic scientists), Price and colleagues (2017) found that postdocs believe that nonprincipal investigators "implement other people's scientific visions through work in the laboratory" while principal investigators are focused on "formulating scientific visions, obtaining funding, and disseminating results through publishing papers and at invited talks" (p. 1). Those postdocs describing the appeal of academic science over nonacademic careers focus on the freedom to be entrepreneurial: "that sense of freedom to go after ideas, come up with ideas, design experiments, ask questions" and "to be your own boss, to do what you want" (Price et al. 2017:5). Those who have worked in industry explain that, while research scientists in those environments might seem to have similar freedoms, they are, in fact, more *intrepreneurial*, a term used to describe scientists whose innovations are constrained by the priorities and goals of their employer. For example, one postdoc observed that

> a project can be cut off at any time, so it's less independence. . . . that doesn't really happen in academics, you know, you find out that you can't fund something, but you can still pursue little side projects even if you don't have direct funding for them. (Price et al. 2017:5)

In explaining his decision to pursue an industry career, a postdoc in another study described his frustration with entrepreneurial competition for resources engaged in by academic scientists. He said,

> [being a professor requires] groveling for money to be able to do science. I don't want to do that. I want to be in the lab performing experiments. . . . [A]nd I'm willing to sacrifice the freedom to work on my own science for that. (Hudson et al. 2018:624)

In this statement, he acknowledges the fact that many nonfaculty scientists, while they might consistently exercise *some* science traits (e.g., science efficacy), are not free to nor expected to employ others (e.g., self-directed, entrepreneurial discovery).

Ultimately, we argue that academic scientists—which most STEM PhD trainees are being trained to be, even if that is not their goal or final destination—are engaged in processes of discovering, evaluating, and competing for opportunities to produce knowledge. Therefore, we argue that there may be traits (entrepreneurial orientations) that some science trainees possess[1] that strengthen their identification with the entrepreneurship-oriented science identity successful academic scientists have. There are a number of traits considered important for entrepreneurial behavior. Three seem particularly appropriate when considering academic entrepreneurship: dispositional optimism (Scheir et al. 1994), innovativeness (Hmieleski and Corbett 2006), and competitiveness (Lumpkin and Dess 1996). We describe each of these in more detail below.

The decision to become an entrepreneur involves having a high degree of optimism (Shane and Venkataraman 2000). Both economic entrepreneurs and academic scientists risk rejection of their products. Hamilton (2000), Singh, Corner, and Pavlovich (2007), and others show that entrepreneurial enterprises routinely fail and when they do not, many still never reap the material gains economic entrepreneurs hope for. Often an entrepreneur's investments do not pay off because new venture creation is fraught with uncertainty. Likewise, academic scientists wrestle with the same dynamics. While failure and rejection of one's ideas are routine—the mice die, the hypotheses are wrong, reviewers refuse to acknowledge the contribution—the work of academic scientists continues mostly unabated in spite of the ever-present ambiguity and vagaries involved in all stages of knowledge production. This is likely a function of their expectations that, regardless of the odds, the challenges faced will be surmounted, and the efforts will ultimately pay off. This tendency to expect favorable outcomes refers to a cognitive construct called dispositional optimism (Carver and Scheir 2014; Hmieleski and Baron 2009). A high level of optimism has been shown to be a major factor in moving people from entrepreneurial thought to entrepreneurial action (Astebro 2003; Benz 2009; Cooper, Woo, and Dunkelberg 1988; McMullen and Shepherd 2006). We suspect that nascent scientists who have developed this trait are similarly more inclined to pursue (or persist in) STEM activities, find success and recognition in them, and have a strong science identity.

"Traditional" entrepreneurs are in the business of discovering and exploiting opportunities to create new knowledge (Shane and Venkataraman 2000). It almost goes without saying that creativity and innovativeness are primary characteristics of entrepreneurs. After all, most entrepreneurs are engaged in either the creation of new ideas, products, or resources or the development of new ways to package and distribute old ideas and products (Hallam et al. 2017; Hult, Snow, and Kandemir 2003; McDaniel 2000). Innovativeness describes a willingness to depart from the norm by viewing situations and approaching existing practices in new and unique ways (Hmieleski and Corbett 2006; Lumpkin and Dess 1996). The ability to combine old resources (material and intellectual) with fresh insights to produce new avenues for scientific investigation and discovery is a fundamental requirement for success for both academic and nonacademic science entrepreneurs. The sign of a successful academic scientist is that they push theoretical and methodological boundaries in ways that contribute to the body of knowledge in their fields in novel ways. In a research setting, innovativeness is a valuable orientation because it involves the process of generating new concepts, identifying new phenomena, and developing new answers to old research questions (McDaniel 2000).

Another fundamental characteristic of economic entrepreneurship—competition—has always been a feature of academic STEM research. From the competition for financial investments from government and industry funding agencies (e.g., National Science Foundation [NSF], National Institutes of Health [NIH]) to the competition for limited space in journals and conference panels, the need to prove that one's work is not only innovative but more worthy than others of receiving access to limited resources is a routine aspect of academic knowledge production. There are well-established expectations that academic scientists, even if engaging in a well-traveled intellectual territory, must establish new ground *relative* to what their peers have done and may be currently doing. Sometimes, this involves doing a better job, relatively, framing their contributions to fit the priorities of funding agencies. Sometimes, this simply involves doing it first. Ylijoki (2003) describes competition as the most characteristic aspect of research in the sciences.

In conclusion, the increased attention to the work of noncommercial academic scientists as "academic/science entrepreneurs" (Casati and Genet 2014; Mars and Rios-Aguilar 2010; Sinell et al. 2015) suggests that examining the relationship between the scientist identity and the entrepreneur identity may be fruitful. Considering the many ways entrepreneurial opportunities are manifested in academic science practices and expectations for promotion, it is safe to say that doing science in the academy is an entrepreneurial enterprise.

Academic scientists engage in the entrepreneurial act of creating new knowledge, a process that requires optimism in the face of uncertainty, an ability to have fresh insights in decades-old disciplines, and a comfort with competing in fields with limited resources. In these contexts, embodying an entrepreneurial orientation is expected and rewarded. Trainees in these contexts learn that these characteristics are as much a part of the meaning of "scientist" as being competent in science tasks and recognized for that competence might be. Therefore, their own assessments of themselves as holders of these entrepreneurial characteristics should be associated with their sense of themselves as scientists. Therefore, we make the following three predictions:

Hypothesis 1 (H1): Dispositional optimism—an inclination to have favorable expectations for one's future, regardless of the odds—will be positively associated with science identity centrality.

Hypothesis 2 (H2): Innovativeness—an inclination to view situations and approach existing practices in new and unique ways—will be positively associated with science identity centrality.

Hypothesis 3 (H3): Competitiveness—a drive to be seen as more capable, knowledgeable, or generally better than others—will be positively associated with science identity centrality.

These hypotheses should not be taken to suggest that we believe these orientations *cause* science identity centrality. Instead, we argue that these traits—like being capable of performing scientific tasks—are characteristic of people who are "scientists." Accordingly, the association between science identity centrality and entrepreneurial orientations should be translated as "someone who considers being a scientist central to their understanding of themselves will be optimistic, innovative, and competitive." We believe those three traits come to define "scientists" and "scientific work" in the ways we have described above.

Data and Method

We used a web-based survey as the principal tool to gather information from 215 STEM postdoctoral appointees.[2] We believe that postdoctoral researchers in STEM, particularly those doing postdocs in academic contexts, are a useful population for this investigation because they are training to become academic science entrepreneurs (see Hayter and Parker 2019 for a review of the ways/reasons postdoctoral training emphasizes *only* this career path).

They are, as a result, more exposed to the culture of academic science entrepreneurship that is often invisible to undergraduate and graduate trainees in science.

In 2017, staff members in the Offices of Postdoctoral Affairs (OPA) at 30 research-intensive doctoral universities forwarded our invitation to participate in the research to their cohort of postdoctoral trainees.[3] The invitation described the parameters for involvement in the research, specifically, that potential respondents be U.S. citizens or permanent residents in the first, second, or third year of their first postdoctoral appointment in one of five broad STEM categories: agriculture and conservation resources, biological and biomedical sciences, STEM education, engineering and computer science, or the physical sciences and math. The OPA staff was informed that we were particularly interested in understanding the experiences of women; as a result, this population was oversampled.

While an accurate accounting of how many potential respondents were exposed to the recruitment materials, more than 750 postdocs responded positively to the invitation. Most of those potential respondents were ineligible to participate because they did not meet the base requirements for inclusion in the study. Ultimately, we ended with a sample of 215 postdoctoral trainees. Of these respondents, 65 percent are women. We weighted our analyses to account for the oversampling that created this imbalance. We used the proportion of STEM postdoctoral recipients (35 percent; National Center for Science and Engineering Statistics [NCSES] 2017a) who are women as a target population for this weighting. The racial balance—77 percent white, 23 percent nonwhite—more closely approximates the percentages of white/nonwhite U.S. citizens and permanent residents with STEM doctorates (NCSES 2017b). More than half (51 percent) of our respondents were in their first year of the postdoc. Representation among the disciplines was as follows: agriculture (6.5 percent), biological and biomedical sciences (56.3 percent), STEM education (3.3 percent), engineering (14.4 percent), and physical sciences (19.5 percent); these percentages differ from the national postdoc population by less than 10 percent (NCSES 2017a).

Key Dependent Variables: Science Identity Centrality

To understand the degree to which our respondents considered "being a scientist" as important to their sense of themselves, we asked them a series of 10 questions developed by Chemers et al. (2011). On a 4-point scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*), trainees indicated their agreement with statements such as, "In general, being a scientist is an important part of my self-image," "I have come to think of myself as a scientist," and "I feel like I belong in the field of science." The items were combined in a scale ranging from 16 to 40 ($\bar{x}$ = 31.84) and treated as a single factor: science identity centrality (α = .84). The mean (on a 4-point scale) of 3.18 is only slightly higher than equivalent measures of science identity centrality in samples of undergraduate and graduate science trainees (Chemers 2011; Stets et al. 2017).

Key Independent Variables: Entrepreneurial Orientations

We measured the trainees' (generalized) favorable expectancies for their future using the Scheir and Carver (1985) Life Orientation Test. Their optimism scale includes 12 questions (four are reverse-coded, four are fillers) aimed at determining the degree to which respondents expect good to come of their efforts and in their future. On a 4-point scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*), trainees indicated their agreement with statements such as, "I always look on the bright side of things" and "I'm a believer in the idea that every cloud has a silver lining." These items were combined in a scale ranging from 1 to 4 ($\bar{x}$ = 2.73) and treated as a single factor: optimism (α = .83).

Innovativeness was measured using the affect and behavior questions from Robinson et al.'s (1991) Entrepreneurial Attitude Orientation Innovation module. These 17 questions measure

Table 1. Bivariate Correlations between Potential Covariates and Dependent (Science Identity Centrality) and Independent (Optimism, Innovativeness, Competitiveness) Variables ($N = 215$).

Variable	Science centrality	Optimist	Innovate	Compete
Science Identity		**.237*** **	**.241*** **	**.244*** **
Optimism		—	.055	.089
Innovativeness		.055	—	.316***
Competitiveness		.089	.316***	—
STEM Discipline (Biology)	.056	.127†	−.069	.112
Postdoc Year (Year 3)	.069	.107	.015	.149*
Interest in Research Career	.160*	.131†	.143*	.047
STEM-experience Covariates				
Viewed as a Scientist by Others	.458***	.121†	−.063	−.063
Degree of Science Efficacy	.298***	.149*	.369***	.369
Undergraduate STEM Major	.003	.031	−.145*	−.145
Few Experiences of Discrimination	.016	.134*	−.065	−.065
Has a Faculty Mentor	.160*	.130†	.068	.068†
Has Nonacademic Experience	−.038	−.004	.153	.013
Demographic Covariates				
Female	−.056	−.011	−.132†	−.112
Nonwhite	−.080	−.084	.041	.007
Age	.019	−.028	.165*	.019

Note. STEM = Science, Technology, Engineering, and Mathematics.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

innovativeness by determining respondents' feelings about innovation (e.g., "I get excited when I am able to approach tasks in unusual ways") and their behavior when presented with a task (e.g., "I often approach research tasks in unique ways"). Trainees were asked to indicate their agreement with the questions on a 4-point scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). The answers were combined in a scale ranging from 1 to 4 ($\bar{x} = 2.91$) and treated as a single factor: innovativeness ($\alpha = .80$).

Finally, the measures used by Lumpkin and Dess (1996) to measure competitive aggressiveness are intended to measure characteristics of firms, not individuals. Instead of those measures, we asked respondents how much the following description feels like them: "A person who enjoys working in situations involving competition with others." The possible responses ranged from *Not like me at all* = 1 to *Very much like me* = 6. This question served as our measure of competitiveness ($\bar{x} = 2.98$).

Demographic Controls and Other Likely Covariates

We control for 12 factors that may covary with science identity centrality. These factors are added into the models in two sections: common demographic covariates and variables related to respondents' STEM training and experience. Means for each of these variables can be found in the first column of Table 2. Correlations between these variables and both science identity centrality and the three entrepreneurial orientations can be found in Table 1.

The first group of possible covariates includes demographic characteristics commonly associated with academic and occupational identity: gender (female = 1), race (nonwhite = 1), and age (continuous variable).

We then control for nine variables reflecting experiences gained in the pursuit of their training in science. The first two represent the postdoc's primary discipline and year in the postdoc. As more than half of the postdocs are

Table 2. Means and Multivariate Regression Testing the Predictive Relationship of Entrepreneurial Orientations on the Degree of Science Identity Centrality in STEM Postdoctoral Trainees ($N = 215$).

Variable	Means	Model I	Model II	Model III
Science Identity	31.84			
Entrepreneurial Orientation				
Dispositional Optimism	0.01			0.125*
Innovativeness	0.09			0.145*
Competitiveness	0.07			0.135*
STEM Discipline (Biology)	0.53		0.055	0.036
Postdoc Year (Year 3)	0.18		−0.060	−0.085
Interest in Research Career	0.81		0.139*	0.111
STEM-experience Covariates				
Viewed as a Scientist by Others	13.83		0.466***	0.463***
Degree of Science Efficacy	41.31		0.244***	0.165**
Undergraduate STEM Major	0.88		−0.038	−0.028
Few Experiences of Discrimination	0.15		−0.030	−0.042
Has a Faculty Mentor	0.79		0.104†	0.078
Has Nonacademic Experience	0.27		0.005	−0.021
Demographic Covariates				
Female	0.35	−0.057	−0.044	−0.007
Nonwhite	0.21	−0.071	0.008	0.008
Age	31.82	−0.010	0.002	−0.003
Adjusted R^2		.005	.289	.341
Change in Adjusted R^2			.284***	.052***

Note. Coefficients are all standardized. STEM = Science, Technology, Engineering, and Mathematics.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

in biological and biomedical fields, we control for that discipline. We would expect that postdocs further along in their science postdoc would have developed a stronger science identity so we control for third-year postdocs (rather than Years 1 or 2).

We also include a dummy variable indicating a preference for a research-intensive career in academia (as either a nontenure-track bench scientist or tenure-track research/teaching faculty), industry, or government. While 81 percent of our respondents list academia as a *possible* career destination, only 42 percent indicate a definite interest in a tenure-track position, with 15 percent of those interested in teaching positions with little to no research expectations. The remaining 58 percent are interested in nontenure-track bench scientist jobs (21 percent), research intensive jobs in industry or government (24 percent), or nonresearch-intensive jobs in industry or government (13 percent).

Using a set of questions commonly used to determine one dimension of reflected appraisals (e.g., my colleagues view me as a scientist, my supervisor[s] view me as a scientist), we created a scale (range = 5–16, $\bar{x} = 13.83$, $\alpha = .90$) indicating the degree to which respondents agree various communities recognize their science identity. We also include a science efficacy scale (range = 26–48, $\bar{x} = 41.31$, $\alpha = .84$) from a set of questions asking respondents to indicate their level of confidence in their ability to perform 12 science tasks (e.g., use technical instruments and techniques, report research results in a written paper). The models also include dummy variables where "1" represents if they have an undergraduate major in a STEM field (i.e., agriculture, biological sciences, science education, engineering, or physical sciences), if they have experienced very little discrimination in STEM environments, if they have a faculty mentor, and if they have nonacademic work experience since receiving their bachelor's degree.

Analytical Strategy

We used ordinary least squares regression modeling to determine the relationship between our three independent variables representing entrepreneurial orientations and the dependent measure of science identity centrality. Each of the three entrepreneurial orientation measures was standardized to a mean of 0 and a standard deviation of 1.

Results

Bivariate Correlations

Table 1 presents bivariate correlations between the dependent (science identity centrality), independent (optimism, innovativeness, competitiveness),and control variables.The first column, labeled "science centrality," shows that four of the controls are associated with science identity centrality in STEM postdocs. The first three—interest in research career, science efficacy, and science community recognition—affirm the findings of prior research. A fourth, that the postdoc has a faculty mentor (79 percent do), is also correlated with science-identity centrality.

The remaining three columns (Columns 2, 3, and 4) present correlations between the variables and the three entrepreneurial orientations. As we predicted, science identity centrality is positively associated with all three orientations: the higher one's science identity centrality, the higher they are on measures of dispositional optimism, innovative mindset, and competitiveness. Of the three entrepreneurial orientations, only innovativeness and competitiveness are correlated with each other.[4] To some degree, innovation is characterized by discovering something new/original before one's competitors do. None of the covariates is consistently predictive of the three orientations.

Postdocs with high levels of science efficacy and few experiences with discrimination are more optimistic than their peers.As our measure of discrimination is constrained to "experiences in STEM contexts," this might serve as a proxy for recognition by one's peers, which is marginally significant in the bivariate analysis.

Four covariates—research career interest, science efficacy, undergraduate STEM major (a measure, ultimately, of long-standing experience in STEM), and age—are associated with innovative mindsets. Of these, the most surprising relationship might be that of age and innovativeness. As the science workforce ages, new research has been done seeking to counter the stereotypes that older employees are less innovative than young ones; the results have been mixed but mostly suggest that age does not decrease innovativeness (Ng and Feldman 2013). Virtually none (3 percent) of our respondents is over the 40-years-or-older threshold for these studies, but this finding supports the trend in that research.

Finally, in regard to competitiveness, only being in the third year of one's postdoc (relative to Years 1 or 2) is positively correlated with a preference for competitive environments. This suggests that more time in (entrepreneurial) STEM environments increases this orientation rather than dampens it.

Multivariate Regressions

In this section, we turn to multivariate analyses of the relationships between science identity centrality and the three entrepreneurial orientations. In Table 2, we provide three models that add, in turn, demographic controls, STEM-experience controls, and then the three entrepreneurial orientations. We report standardized coefficients in the Table, but provide both unstandardized and standardized coefficients here in the text.

Consistent with the bivariate statistics, we determine that the demographic controls explain none of the variation in the degree of science identity centrality of our respondents. None of them is significant. This is surprising, as past research on undergraduates and graduate students in STEM suggests some of these variables—particularly race and gender—are associated with differences in science identity centrality. It may be the case that STEM postdocs, who are much further along in their science careers than (under)graduates, have developed a stronger sense of self in terms of their science identity in general, both as a by-product of a longer time within the science community (and, therefore, more opportunities for recognition and positive appraisals) and a by-product of chronic racial and gendered micro-aggressions, which have "hardened" their sense of self and weakened the effects of discrimination.

The STEM-experience covariates add much more (R^2 = .288) explanatory power to Model II. As suggested by the bivariate correlations in Table 1, having an interest in a research-intensive career is positively associated with science identity centrality (B = 1.57, β = .14, p = .02). The two variables most commonly associated with science identity centrality—being viewed as a scientist and science efficacy—are also both significant and positively correlated with science identity centrality in our model. The more postdocs believe others view them as scientists (B = 0.88, β = .47, p = .00) and the more they believe themselves capable of completing science tasks (B = 0.23, β = .24, p = .00), the stronger their sense of themselves as a scientist. The other variables (e.g., STEM undergraduate major, third year in postdoc) do not predict degree of science identity centrality.

That leaves our final, full model, Model III. The inclusion of the entrepreneurial orientation measures has considerable effects on the model, increasing its explanatory power by an additional 5 percent (R^2 = .341). All three of the entrepreneurial orientations are significant. Innovativeness, optimism, and competitiveness are all positively associated with increases in science identity centrality. Of those three measures of entrepreneurial orientation, the innovativeness variable was the best predictor in the set (B = .62, β = .15, p = .03), followed by competitiveness (B = .62, β = .14, p = .03) and then optimism (B = .57, β = .13, p = .03). Only two covariates remain significant in this full model: science efficacy (B = 0.16, β = .16, p = .00) and the strongest variable in the model, being viewed as a scientist (B = 0.87, β = .47, p = .00). Interest in a research-intensive career is only marginally significant in the final model (B = 1.26, β = .11, p = .06).

Discussion

This study explored the relationship between entrepreneurial orientations and science identity centrality. Scientific research is fraught with uncertainty. Failure is routine: the hypotheses are wrong, editors reject great work, the treatment does not work. As STEM research and knowledge production, in and out of academic contexts, is often characteristically precarious and uncertain, having the propensity to approach potentially adverse situations with positive expectations is a useful disposition for a scientist to have. In addition, as the academic market for STEM careers both encourages and rewards rivalry and originality, being able to not only create new things but to endeavor to create these new things *before* or *better than* others seems integral to developing a science identity. We posited that three entrepreneurial traits would have a positive relationship with science identity centrality: dispositional optimism, innovativeness, and competitiveness. That is, we hypothesized that the more a person had of each of these qualities, the greater their sense that they were, in fact, a scientist.

Our results indicate that dispositional optimism, innovativeness, and competitiveness are associated with science identity centrality among STEM postdoctoral students. Those who have positive expectations for their future endeavors, those who recognize and carry out pursuits in new and unique ways, and those with a propensity for outperforming competitors tend to more strongly consider being a scientist an important part of their identity.

The results of this study contribute to existing research on motivations to pursue and persist in STEM. Although science efficacy/recognition and the interventions designed to strengthen them are useful for insight into people's engagement in science production and performance at such high levels, they only constitute part of the story. Our research further fills a gap in the literature on STEM commitment by examining the relationship between entrepreneurial values and science identity centrality to argue that the kind of dispositions associated with entrepreneurial identities may also be associated with scientific identities, particularly among academic scientists. The science research performed by academics (including postdocs in academic settings) is an entrepreneurial enterprise. Desires to produce and disseminate knowledge likely stem from the same impetus to discover and exploit opportunities that is commonly attributed to entrepreneurs. This being the case, research on motivations to engage—and, ultimately, persist—in STEM research production should also consider how holdings of entrepreneurial dispositions might facilitate these outcomes.

A second contribution is its focus on postdoctoral trainees. Relative to research about STEM trainees at all other levels (i.e., undergraduate, graduate), research about postdoctoral trainees is scarce. Their liminal stage—as terminal degree holders who are temporarily "employed" in academic bench scientist roles—makes them appear to be simply members of the gig economy workforce like the soft-money bench scientists many of them work alongside. As a result, they are often ignored in research on STEM trainees. We believe they are neither gig-workers nor, for the most part, being trained to be gig-workers. They are being trained to be entrepreneurial academic faculty like the principal investigators they work with (not just "for"). Nearly all (96 percent) of our respondents say their postdoctoral department encourages them to pursue academic-science careers; 64 percent report "strong" encouragement to do so. As taking on a postdoctoral appointment is becoming almost normative in STEM disciplines, particularly in the biological and biomedical sciences, understanding the behaviors, motivations, and issues of identity of individuals at this level is important for building a more complete picture of influences on attrition from and persistence in STEM disciplines and academic careers.

Finally, we provide insight into the study of entrepreneurship beyond that of "traditional" entrepreneurial fields and contribute to a burgeoning research niche on academic and scientific entrepreneurship. We agree with Mars and Rios-Aguilar (2010) who argued that

> the narrow interpretation of the economic and managerial frameworks of entrepreneurship has made higher education scholars blind to the merits of entrepreneurship as a conceptual and theoretical approach to the analysis of innovative, but non-market oriented activities and behaviors of those within the post-secondary academy. . . . (P. 453)

By continuing to overlook the fact that academic scientists are engaged in entrepreneurial activity, even when the goal is not to monetize their findings, researchers are unlikely to achieve a full appreciation of the values that motivate commitment to academic science careers. We suspect this same oversight exists in examinations of other entrepreneurial spaces (e.g., churches, professional orchestras, political campaigns) where we, incorrectly, believe entrepreneurship is not occurring because there is no concomitant profit motive. As a result, we are likely missing ways that professional identities associated with those spaces (e.g., clergy, concertmasters, politicians) might be shaped and defined by the entrepreneurial activities they engage in.

This study is not without its limitations. We recognize that the generalizability of this study is limited by the fact that our conclusions are drawn from a postdoc-only sample. Evidenced by the pursuit and successful completion of a science PhD, STEM postdocs are likely to have strong science identities. The strength of the science appraisals and science efficacy covariates highlight this reality. In that sense, STEM postdocs are "extreme cases" compared with a sample comprised of undergraduates or, even, graduate students in STEM disciplines. Given this limitation, it is all the more interesting that even among these extreme cases, entrepreneurial orientations were still useful for predicting science identity centrality. Optimism, innovativeness, and competitiveness still provide meaningful insight into factors that drive science production, even among individuals who have been pursuing careers in science through at least two college degrees (89 percent of our postdocs have STEM undergraduate degrees). Certainly, our understanding of these phenomena would benefit from applying our analysis to undergraduate and graduate students in STEM disciplines as well.

Another limitation is our inability to make any claims about causality, that is, whether having entrepreneurial dispositions leads to, rather than is simply associated with, a stronger science identity. The current study is a cross-sectional analysis and the ordered relationships between the entrepreneurial traits and science identity cannot be established. A longitudinal study would be more appropriate for assessing the timing of scientists' development of entrepreneurial traits relative to their science identity to establish a causal relationship. Nevertheless, we contend that the positive relationship between the two suggests development of one would, at least, be accompanied by the development of the other.

This contention has practical implications, particularly for STEM departments training students at all levels (i.e., BA, PhD, postdoc). Efforts to increase participation and persistence in STEM may benefit from the incorporation of entrepreneurial trait development into their agendas. Research suggests that entrepreneurial traits such as dispositional optimism, innovativeness, and competitiveness can be developed (Robinson and Stubberud 2014; Seligman 2006). Policies and programs focusing on improving participation in and commitment to STEM should not be solely concerned with science methods and content. Instead, these efforts should also aim to teach entrepreneurial skills. Incorporating problem-solving exercises or case competitions in STEM courses, for example, would be useful for promoting innovativeness and competitiveness. Creating opportunities for science students to fail and learn how to process failure can foster dispositional optimism (Seligman 2006). Alternatively, STEM programs could outsource these efforts. Business schools and management courses often teach business students entrepreneurial dispositions and skills. Thus, academic science departments could partner with professors in business schools or courses to give STEM students exposure to courses where these skills can be developed.

Future research in this area could extend our findings in at least two ways. First, if these three dimensions of entrepreneurial orientations are useful for understanding the occurrence, if not the development, of science identity centrality, how could our understanding further improve with other measures of an entrepreneurial orientation such as risk-taking, proactivity, and autonomy (Lumpkin and Dess 1996)? The inclusion of these variables could support or challenge our current understanding of the relationship between entrepreneurial orientations and science identity for researchers in the academy. Second, given the STEM literature's recognition that science identity centrality is a contributing factor in persistence in STEM, it would be a worthwhile extension of our findings to determine if entrepreneurial orientations have either a direct or indirect effect on persistence in STEM disciplines and, ultimately, STEM careers. Given our sense that engaging in STEM research in academic contexts (vs. working as a bench scientist in industry or government) is especially entrepreneurial, gaining a better understanding of the impact of entrepreneurial orientations on persistence may help solve some of the issues raised by scholars concerned about attrition from academic careers (e.g., Gibbs, McGready, and Griffin 2015).

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Notes

1. Whether these traits are innate, learned, or some combination of the two is contested territory among entrepreneurship scholars (Frese and Gielnik 2014; Zhao, Siebert, and Lumpkin 2010). As we will discuss in the conclusion of this article, evidence exists that these traits can

be developed. Our findings suggest there may be some benefit to pursuing that aim.

2. We also completed interviews with 60 respondents. These interviews confirmed—like those of Price et al (2017) and Hudson et al (2018)—that postdocs consider academic-science environments to be entrepreneurial ones requiring optimism, innovativeness, and competitiveness in order to be successful.
3. In all cases, the offices were not allowed to give us names and other details of their postdoctoral population. As a result, we could not constrain the list of invitees to only those postdocs who met our study parameters.
4. While dispositional optimism has been shown to be a distinct characteristic of entrepreneurs (see Crane and Crane 2007 for a review), it has been inconsistently demonstrated to relate to other entrepreneurial characteristics. For example, in an unpublished study, Liang and Dunn discover that optimism is correlated with risk acceptance but not to desire for independence, two characteristics often cited in the entrepreneurship literature. This suggests a need for further refinement of the characteristic when applied to entrepreneurs.

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