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Factors Affecting the Occurrence of Faculty-Doctoral Student Coauthorship

Using faculty narratives, this study identifies factors affecting the occurrence of faculty-doctoral student coauthorship. Norms of the discipline, resources, faculty goals for students, faculty goals for themselves, and institutional expectations emerged as dominant factors. Each factor is explored separately and as part of an interlocking holistic picture.

Among scientists, writing is a critical activity. Written text allows science to be preserved and transmitted, and serves as “a constitutive part of science . . . [which is] inextricably linked to the very nature and fabric of science” (Norris & Phillips, 2003, p. 226). For scientists in academe, writing is often described with the maxim ‘publish or perish’ (McGrail, Rickard, & Jones, 2006), and publication quantity is a common measure of scientific productivity for individual academicians, departments, and institutions (Toutkoushian, Porter, Danielson, & Hollis, 2003). Often, the number of publications counts, literally, in tenure and promotion deliberations (McGrail et al., 2006).

Writing experiences are also associated with the advanced development of scientific reasoning skills (Keys, 1995). Scientists report that

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The Journal of Higher Education, Vol. 84, No. 1 (January/February)
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writing improves the clarity of their ideas, helps them to generate new insights, and facilitates their synthesis of information in new ways (Yore, Hand, & Florence, 2004). In particular, the scientists participating in Yore et al.'s (2004) study valued the reflection and metacognition that writing encouraged, describing the writing process as a means of evaluating the validity of their own claims and arguments. One even likened it to "a very high level teaching experience" (p. 361).

For doctoral students intending to pursue a professorial career, publishing prior to graduation is a growing expectation (Nettles & Millett, 2006) and part of the socialization process into disciplinary and academic cultures (Kamler, 2010). Early publication productivity is linked to initial post-graduation career placement and development (Ehrenberg, Zuckerman, Groen, & Brucker, 2009) and greater productivity in later years (Kademani, Kalyane, Kumar, & Mohan, 2005). Of equal importance, students develop and strengthen their own scholarly identity through the coauthoring process (Kamler, 2008). Thus, "it is clearly important for science that its most junior members learn how to be productive in the traditional sense of developing peer-reviewed presentations and publications" (Seashore Louis, Holdsworth, Anderson, & Campbell, 2007, p. 312).

A handful of studies have investigated how graduate students in the sciences learn to write for publication (e.g., Chaopricha, 1997; Florence & Yore, 2004; Kamler, 2008). All highlight the collaboration between faculty mentors and graduate students in producing scientific publications, with Kamler (2008) suggesting that without faculty to initiate the process, many students fail to publish at all. The centrality of faculty mentors in this activity is not surprising, given their overall importance in graduate students' development as researchers (Austin, 2002; Felder, 2010). Without mentors' intervention, students are left with the relatively limited guidance offered by observation, peers, informal networks, self-help books, and trial and error as they learn how to write for their respective disciplines (Paré, Starke-Meyerring, & McAlphine, 2007). Thus, faculty mentors who coauthor with students serve as *de facto* gatekeepers into disciplinary discourse communities (Florence & Yore, 2004) that communicate using specialized knowledge and language (Harrison & Stephen, 1995).

Contextual Background and Conceptual Lens

This study recognizes scientific work as grounded within social settings (Fox & Mohapatra, 2007). Lee and Aitchison (2009) concep-

tualized academic writing as a “socially-situated and socially-constructed . . . event shaped by power relations and with personal and social consequences” (p. 91). As the enterprise of scientific inquiry evolves, these interconnections among people become increasingly salient, and the traditional conceptualization of scientific achievement as an individual accomplishment has yielded to views of science as a collaborative undertaking (Radinsky, Oliva, & Alamar, 2010). Overwhelmingly, modern scientific work occurs in teams, organizations, and within larger communities of science (Dunbar, 2000; Fox & Mohapatra, 2007).

According to authorship guidelines released by the National Academy of Sciences (Committee on Science, Engineering, and Public Policy, 2009) and used by *Science*, *Nature*, and the *Proceedings of the National Academies of Science* (Alberts, 2010), such collaborative efforts typically warrant acknowledgement through coauthorship. In a reflection of this trend, Kamler (2008) found that coauthorship between faculty and their doctoral students appears to be a more established expectation in the sciences than in other disciplinary areas. Despite expectations for and importance of coauthorship between STEM (science, technology, engineering, and mathematics) faculty and doctoral students, there is little investigation into factors that promote or inhibit this type of collaboration. At a broader level, however, collaboration between campus constituents has become a critical topic in higher education. Accrediting agencies eagerly inquire into collaborative campus efforts that boost student learning outcomes (Kezar & Lester, 2009). Decreases in traditional funding sources for higher education spur partnerships between campuses and industry (Ehrenberg, 2006). Further, external funding agencies increasingly value collaborative disciplinary efforts (Borrego & Newswander, 2010; National Science Foundation, 2006).

In light of the trend toward increased collaboration, Kezar and Lester (2009) examined several postsecondary institutions that documented their move from reliance on traditional individualistic norms to those more supportive of collaborative work. Their efforts generated a model of collaboration in higher education settings that speaks to a scope of involvement beyond that of faculty-student coauthorship. Although neither the model’s scope nor its format is perfectly tailored to this study, the model does offer a supportive conceptual lens. It identifies contextual factors that facilitate collaborative efforts at the institutional level, which are mirrored to some extent in smaller collaborative efforts such as faculty-student coauthorship. Additionally, Kezar and Lester’s model emphasizes that factors affecting collaboration should be examined as

both separate elements and as part of an interrelated whole. Finally, as Kezar and Lester (2009) found, fostering collaboration requires institutions to integrate “structure, rewards, resources, hiring, and formalize the network” (p. 224) for collaboration, which leads to “rethinking overall organizational structures, processes and design” (p. 225).

This study identifies those factors most influential in driving faculty-student coauthorship. This effort is part of a larger project examining the impact of science graduate students’ teaching and research experiences on the development of their research skills (Feldon et al., 2011). As this larger study unfolded, we observed that a select number of graduate students and faculty advisors identified their coauthoring experiences as contributing positively to the students’ research skill development. However, reports of faculty-student coauthorship were not universal. Thus, the broad questions arose:

1. What factors influence the likelihood that faculty-student coauthorship will occur?
2. What interactions emerge between these identified factors?

Method

Faculty-student coauthorship occurs as part of a complex, holistic university milieu. The nuances of the relationship between faculty and their students, peers, and institution and with their own career trajectories require that individual circumstances and perspectives be carefully considered to gain insight into writing collaborations. Thus, we elected to conduct individual interviews in which participating faculty had ample opportunity to reflect on the circumstances and perspectives underlying their decision to coauthor with their students.

Participants

Participants in the larger study included graduate students in STEM disciplines at the master’s degree or doctoral level and the faculty members whom these students identified as their primary supervisor or mentor. As patterns emerged from the data we collected, we noted that a distinct subset of faculty-student pairs discussed—unprompted—their engagement in collaborative writing. Both faculty and students attributed growth in students’ research skills to this practice. However, within the larger study of more than 100 faculty-student pairs, this group constituted only approximately 20% of our participants. It is possible that other faculty-student pairs engaged in collaborative writing practices, but they did not discuss them during their interviews.

In a collective review of all interview data from the project, we identified those faculty who discussed collaborating with their students. To be included in this sample, we did not require a faculty member to be currently writing with a student. We did, however, review each faculty member's curriculum vitae to verify a track record of writing with doctoral students. We focused on faculty who coauthored with doctoral students (as opposed to only master's degree students) because the ability to master academic writing is especially important to doctoral students, as their work is "judged in terms of its contribution to the field of knowledge or practice that it inhabits" (Lee, 2010, p. 17). In this manner, we identified 17 STEM doctoral advisors who coauthored with their doctoral students. We identified 2 additional STEM doctoral advisors who coauthored with their doctoral students through a snowball sampling method (Denscombe, 2007), in which participating doctoral advisors identified other faculty in their respective departments who wrote with doctoral students.

Of the 19 total faculty participants, 5 were female. The smaller number of female participants reflects the reality that female faculty are underrepresented in STEM disciplines (Hill, Corbett, & St. Rose, 2010). All faculty participants served as tenure-track or tenured faculty at a large research-intensive university (Carnegie Classification RU/VH, formerly known as "R1") in the southeastern United States (Carnegie Foundation, 2009). Most had established a record of publication that included several works coauthored with their doctoral students. Participants' disciplines and faculty ranks are detailed in Table 1.

Data Collection Procedures

Each of the 19 faculty participants was individually interviewed either in person or by telephone. The interview protocol used in this study was developed through review of relevant literature on faculty-student coauthoring, focusing especially on coauthoring in the sciences (e.g., Chaopricha, 1997; Florence & Yore, 2004; Kamler, 2008). Reflection on our own experiences as faculty members who coauthor with students was also useful in the development of the interview protocol. The protocol contained semi-structured questions representing four primary domains: faculty motivation for writing with students; description of faculty-student writing process; outcomes of writing process, in terms of student skill and identity building; and contextual factors affecting faculty's decision to write with their students. Interview probes for the domain of contextual factors encouraged the faculty member to consider factors at the individual, institutional, and disciplinary level as well as any other influences that might fall outside those categories. In general,

TABLE 1
STEM Faculty Participants' Coauthorship Rates by Rank and Discipline

Discipline	Tenure Rank								Total # of Faculty
	Assistant		Associate		Full		Total # of Faculty		
	# ^a	% ^b	# ^a	% ^b	# ^a	% ^b	Field	Field	
Science	8	50	27	4	100	40	7	7	
					Geog			Biol	
					Geog			Biol	
Engineering	9	100	52	98	151	93	8	8	
					Chem			Chem	
					Civil			Chem	
					Civil			Elec	
Math & Statistics	17	6	19	42			4	4	
					Math			Stat	
					Math			Stat	
Average ± SD	12 ± 4.4	41 ± 44.5	24 ± 14.8	40 ± 31.5	72 ± 37.0	62 ± 29.0			
Total # of Faculty		4		7		8		19	

^a Total number of publications by that faculty member at his/her time of study participation.

^b Percent of that faculty member's publications coauthored with graduate students.

Note: The overall average rate of coauthorship with students across all fields and ranks is 49.3 + 33.2%.

the length of interview time specifically focused on response to these above questions averaged about 30 minutes. Some, however, lasted up to 50 minutes, as some faculty offered lengthy narratives of particular writing experiences or procedures. All interviews were recorded and transcribed.

Analytic Procedures

Initially, we anticipated using all interview data to inform one paper examining the antecedents, processes, and outcomes of the faculty-student coauthoring experience. However, as analysis proceeded, we realized that the amount and rich nature of data required more restricted foci to maintain conceptual clarity and rigorous systematic inquiry. Thus, the current paper draws only on data collected in response to first domain questions (faculty motivations) and fourth domain questions (contextual factors). Preliminary analysis indicated these two domains overlapped; as such, they were combined for analysis.

Two separate investigators reviewed the selected data to identify initial themes in participants' responses. This review used the constant comparison approach (Glaser, 1965) in which investigators constantly compared emergent themes both within and across transcripts. Initial themes were then repeatedly reviewed and discussed to facilitate a fine-grained, shared understanding of their nature and scope. Contextual factors were first coded into those that occurred at the individual, institutional, and organizational levels, respectively. However, we soon determined that these codes were not mutually exclusive. That is, any one factor (e.g., faculty members' discussion of the influence of tenure and promotion criteria on their decision to coauthor with their doctoral students) could be coded as occurring at more than one level (e.g., both the individual and institutional levels). Our analyses instead revealed that almost all data could be aligned with five emergent, interconnected themes, reflecting a parsimony suggestive of theoretical saturation. Together, these five themes presented a holistic portrait of factors affecting the occurrence of faculty-student coauthorship. Individual themes and their interconnections within this holistic portrait are detailed in the following section.

Findings

Five emergent factors were identified and labeled as follows: Norms of the Discipline, Resources, Faculty Goals for Students, Faculty Goals for Themselves, and Institutional Expectations.

*Norms of the Discipline:
"The Students Are Like the Cast and Crew"*

Norms are implicit or explicit guidelines established by a group to regulate the behavior of its members (Baron & Byrne, 1991). Norms are central to socialization, here defined as "the processes through which an individual learns to adopt the values, skills, attitudes, norms, and knowledge needed for membership in a given society, group, or organization" (Gardner, 2010, p. 63). Faculty members were quick to indicate their adherence to prevailing disciplinary norms. Their own socialization to publication, coupled with disciplinary norms of coauthoring with students, emerged as key factor subthemes.

Most faculty members described—often at length—their own socialization to authorship. Socialization narratives varied dramatically, aligning with the broader literature depicting the doctoral experience as one in which students express concerns about uneven mentoring and unclear performance expectations (Austin & McDaniels, 2006). Some advisors were highly involved, as in the case of an engineering professor who observed, "I would write a manuscript and the page would come back red with diagrams about where pieces of sentences should go and what words should be added where." Others were disengaged or worse, such as described by an exercise science professor: "I came through with a guy who was pretty secretive. It was not easy to be on a paper with him."

Overwhelmingly, doctoral advisors socialized these faculty members and former doctoral students into academic writing through coauthorship. Occasionally, postdoctoral fellowship supervisors and doctoral student peers also played a role. This finding aligns with those of Austin (2002), Gardner (2010), and Sweitzer (2009), who noted the importance of peers and others in doctoral students' professional development.

One participant, a professor in geography, learned to publish through his own efforts, but noted:

I was very fortunate that in graduate school, the [institution attended] was an absolute power in [participant's field] when I was there, and a lot of us were publishing very early on. Because I was surrounded by so many people who were publishing and faculty who didn't work with me per se, but who were engaged with publications, I figured out how publish.

Discussions of faculty-student coauthorship occurred across disciplinary affiliations, although they were less frequent in mathematicians' responses. As one engineering professor mused, "The lore is that in math, pure math, it is single authorship." Mathematicians in this study

wrote with their students; they also described writing individually (“I always have one or two projects going on that are just my own”), an activity rarely reported by science and engineering faculty. Instead, these participants detailed clear disciplinary norms for division of labor, as described by a chemistry professor:

In chemistry, graduate student coauthors are the norm. They do all the labor, in the sense of lab experiments. I give the analogy of movie-making as being like science. The professor is the producer, director, and to some extent the screenwriter; the students are the cast and crew.

Resources: Tied to Funding, Out the Door, and Mr. Wizard’s Science Experiment

Resources, both in their presence and absence, were frequently mentioned in relationship to faculty-student coauthorship. Key resources included funding, time, and skills or attributes. These resource categories continually overlapped. A deficit in one consumed more of another, while a rare abundance of one generated greater margins of error for the next.

References to funding resources were largely absent from mathematicians’ narratives but permeated those offered by scientists and engineers. As an engineering professor explained:

[Faculty-student coauthorship] is so heavily tied to funding. If you are funded, then you are funded to hire people to work with you, and a measure of success is that these people have done quality-enough work under your direction to publish. So, yeah, it is significant enough to publish with students. That is a measure that you have a program, you have a project, you have a center, and you have a group. The success of your group is what you are after, and so your group’s name better be on it.

External funding underwrote the essential ingredients supporting coauthorship, including student research assistantships, specialized equipment, conference travel, and space. As one professor of engineering despaired, “Space is an issue; this campus is growing like crazy. If I lose the funding, guess whose labs they are going to go after?” Lack of external funding, predictably enough, curtailed coauthorship. In departments without it, doctoral students often taught. A professor of geography described a situation in which his doctoral student taught a class with 200 students. He surmised, “If she didn’t have the 200-person class, I could say, ‘Look, you have to publish, we have to publish more together.’ This has been a problem.”

Time availability was a frequently cited factor, although its perceived impacts varied. Some accounts were of coauthorship expanding faculty time. For example, a geography professor coauthored with students because “I wanted to write about two things that had been bugging me, and I just did not have the time to go after these things by myself.” An engineering professor pondered, “I just had never conceived that it [not writing with students] could be possible to—I just don’t have the time to do all the writing myself, even if I wanted to.”

Additionally, peer exchange expanded faculty time, as observed by a chemistry professor:

You get five to ten students working in parallel and if they get stuck, they are in the lab all the time, they can ask each other, because the professors are also trying to teach classes, be on committees, go to conferences, write grants, so their time gets filled up pretty quickly, so it is actually a pretty efficient way to get science done.

More commonly, time availability was framed in terms of competing job obligations, the race toward tenure, and student skill level. Administrative work consumed faculty time, stealing it from writing. As one engineering professor observed, “I have an extraordinary amount of administrative work in being the acting director of the program. That certainly takes away from my ability to push on the publishing side.” The constant quest for funding also took a toll on writing for publication, as noted by another professor of engineering: “Trying to keep the group funded has taken up most of my time.”

When faculty did have time to write with students, they did so with the realization that it often took longer to write with them than without them. For pre-tenured professors, this proved troublesome. As an engineering professor noted, “Those first five years, you have to get things out the door, and it is really important to do things very, very quickly, so I would just do it myself.” Advanced student skill sets speeded the writing process, as another engineering professor explained:

With students who can write well and provide a first draft that is in good shape grammatically and in terms of conceptual organization, we can get right past that to “Does the manuscript tell the kind of story that we want to tell?” and we can rapidly adjust that and get it out the door quick.

Conversely, students with lower skill sets required additional faculty time. As an exercise science professor explained, “It just depends on what I have going as far as the time. Every few days they give me a

printout and then I would basically rewrite the whole thing.” As one pre-tenured professor of mathematics lamented, “If the student doesn’t have the research skills, then you have to sit next to them and really work with them. The time you spend with your graduate students one-on-one is not counted toward your teaching load, and that is an issue.”

Student skills emerged at the third key resource, and their inconsistency caused concern. As a geography professor observed, “I am working with more senior students and I don’t have a lot of unevenness. It depends who you have. Right now I am blessed with good students, and that is not always the case.” An engineering professor stated that students with strong writing skills “just help you produce and publish, and you watch your papers be cited.” Conversely, faculty found it “painful” to write with students of weaker skills. Students’ reading and writing skills captured the majority of faculty attention in this area. Critical research skills included students’ ability to, as an engineering professor explained, “set it in the context of what other people have done, and say why it is interesting.” Another engineering professor elaborated:

I am convinced that the reason everyone has difficulty writing is that they don’t know what to say and they don’t know what they’ve done and they don’t know what is important about it because they haven’t read the literature. So, they don’t know where their work fits in. The default paper I get from a student looks like *Mr. Wizard’s Science Experiment*. “Here’s what I did! I went to the lab and I did this and this! And here are the graphs!” And the response I always have for them is, “Why does anybody care? Nobody else in the world has exactly the problem they worked on and so you have to generalize the results—you have to tell someone why this is interesting to them.”

Faculty observations on students’ writing skills also permeated their narratives. As one engineering professor lamented, “Students need to have good writing skills. You may have a student who cannot put a paragraph together, you know, they just download random thoughts, or they *completely* miss the point, and that happens a lot.” Additionally, some faculty noted that students who were not native English speakers struggled with writing. As a mathematics professor who herself was not a native English speaker noted, “I learned that how you write a paper is very different than how you speak, and this is a problem, especially if you are a foreigner, and the words are not always stable.”

To strengthen students’ research and writing skills, one engineering professor offered a summer writing class for his students. However, this

type of intervention was a rarity, and most faculty were dismayed over the lack of research and writing instruction available to students. As an engineering professor explained, “We are not telling students: ‘This is actually how you write.’ It is more just experience and banging your head with your faculty advisor.” Faculty noted that this level of time commitment could be a deterrent. As an exercise science professor noted:

With students you have to be willing to work for it with them, and there are some faculty who are fairly impatient, or they only want to recruit students who are very good writers. If you don’t have that luxury, you are going to have to work with students, because quite frankly the writing ability of a lot of students anymore isn’t very high. So you have to have the patience to give them some feedback, and that takes time.

***Faculty Goals for Students:
“They’re Going to Be Writing for the Rest of Their Lives”***

Faculty uniformly recognized opportunities for academic and professional development inherent in students’ engagement as coauthors. Academic development goals emphasized strengthening research and writing skills identified in the previous section: familiarity with relevant literature, contextually placing one’s work within the disciplinary dialogue of the literature, shaping the story of the paper, learning to neither over- nor understate the relevance of findings, and learning about the revision process. As one mathematics professor summarized, “So students realize, ‘Oh, this publication process is not a trivial thing.’”

Additionally, faculty wanted their students to learn to collaborate. As another mathematics professor explained:

Learning how to collaborate with others is important because when you work with others, you learn a lot more than just working with yourself. Every person brings a different perspective to the problem, so you have a lot more understanding of the problem. With all these different perspectives, you have to provide a somewhat proactive environment for the student, or certain things might lead to hurt feelings. So you use a lot of techniques to teach them, and that is very different than what students might get in a classroom; it is a much more intense experience.

In terms of professional development goals, faculty discussed the importance of students establishing a publication record as a precursor to an academic career. As a geography professor stated, “My students come out of here with two to three publications, at a minimum. I’ve sat

on hiring committees, and I know what good applications look like. I make sure my students look like those applications.” This sentiment was echoed by a statistics professor, “I require them to write papers before they apply for a job. Otherwise, they can’t compete.”

Faculty also recognized that regardless of their students’ intended career path, they needed strong scientific writing skills. An engineering professor commented, “It depresses students to hear that eighty-five percent of my job is writing,” while a chemistry professor observed, “No matter what kind of scientists [students] end up being later, they are going to have to write documents that will have to justify their existence to somebody.” A second engineering professor agreed, stating, “They are going to be [writing] for the rest of their lives. Whether or not they stay in the engineering field, they are going to be doing a lot of writing.”

Faculty Goals for Themselves:

“Must Write Papers, Must Write Papers, Must Write . . .”

Faculty also identified several desired outcomes for themselves associated with student coauthoring. These desired outcomes fell into one of three categories: individual interest goals, mentioned by a small number of faculty, and two goals mentioned by a majority of faculty—namely, the goal to increase researcher status and the goal to meet institutional expectations or requirements. Individual interest goals included knowledge distribution (“The paper is never as wonderful as I would like it to be, but still, there are some ideas worth sharing.”), benefiting from student content knowledge or expertise (“Honestly, I don’t feel like I am as aware of the significant things in the field as the student is by the time that they get to the point that they should be at when they are writing their papers.”), the combination of teaching and research (“I try to structure seminar projects in a way that would result in some form of publication.”), writing on topics of interest (“It allowed me to get some thinking and writing done on topics I was really interested in.”), and building one’s professional network (“As a personal goal, I would like to have more faculty members that have been students of mine in the different universities because that increases the size of the team that you can collaborate with.”).

Within faculty narratives, researcher status was perceived to increase as number of publications increased. Writing with students often (but not always) resulted in publications, thereby bolstering researcher status. Faculty coauthored with students not only to facilitate students’ development but also to facilitate the development of their own professional reputation. Steps taken toward professional reputation development aligned with those taken to meet perceived institutional expect-

tations or stated requirements. Thus, explanations such as the following were common:

We push this [coauthoring with students] in our department and we get a lot of credit for it at the university. They like the idea of student authorship. I've even seen where they (university officials) add up and say, 'He's mentored so many students on papers.' So in our area the last author is called the senior author. Because really, when you start to show that you are independent and doing your own work, you show up as the senior author, that is sort of a status thing. It is a nice transition for us that we become the senior author, which is the last author, and we let our students run the study and become the first author. They just have to do enough work to take that position. (exercise science professor)

In terms of labor involved, you can't do anything without your students, and you are not going to get papers out unless you have students, and the papers you get out pretty much determine your status. So if you have lots and lots of really good papers, people will know who you are, and invite you to conferences and you get promoted. So everything points to 'yes, you must write papers, yes, you must write papers.' Certainly, if you want to get tenure, some universities in chemistry have number requirements, you have to publish X number of papers. (chemistry professor)

***Institutional Expectations:
"Not Everyone Can Read, but Everyone Can Count"***

For both students and faculty, striving to meet institutional requirements and expectations shaped the drive toward publication. Professors of engineering and science were quick to note their respective departmental requirements for pre-graduation student publications. Papers fulfilling these requirements were almost always coauthored with one or more faculty members, although standards appeared to vary, as apparent in the following statements from faculty: "To graduate, they (students) need to have at least published one paper and in most of the departments it is like three, although one could be a conference paper"; "Yes, we require three papers submitted by their defense. You have to show that they were submitted, not published"; "They are required to be coauthors on at least three manuscripts submitted for publication, but most successful students have more than three manuscripts and are the primary or lead author on several."

Pre-graduation publication requirements for doctoral students in mathematics and statistics appeared more nebulous. As a statistics professor explained:

It is interesting that you point that (a rule requiring students to submit a paper prior to dissertation defense) out, because we have kicked that around a lot in the last year or two. It is not really a departmental guideline. No one disagrees that to be a passable dissertation, it ought to be publishable, but there is variability from faculty member to faculty member as to whether they are going to require the student to actually submit it before they defend. So it is not a departmental rule, although it almost became one last year. It was proposed, and it was debated at length, and finally it was just sort of tabled.

Faculty reacted to institutional expectations for publication based on career stage. For pre-tenure or just-tenured faculty, tenure and promotion guidelines loomed large and were coupled with the need to show one's ability to mentor doctoral students. As a pre-tenure math professor noted, "A big issue is promotion. What do I have to do to be promoted? Writing with a student is not a problem, it doesn't take anything away from me. In fact, it is part of my job." A just-tenured chemical engineer professor observed:

For me to get tenure and promotion and succeed at my job, I have to get publications that come out of my lab not just with my name on them, but that show that I have been doing my mentoring job to show that the work is coming from people working within my lab.

However, this sentiment was not universally shared. As a tenured geography professor noted:

In terms of going up for promotion and tenure, maybe not for full professor, but for tenure, we actually look a little bit and we don't want people to publish with students as much then, because we want them to show that they can do stuff on their own. We don't want a student to actually do their (the faculty member's) work, so I think that counts for later promotion; at least that is what I am told.

Post-tenured, mid-career faculty did not escape the pressures for publication. When asked why he wrote with students, an associate professor of geography responded, "For a promotion a little higher up, they look for how well you've mentored your graduate students. I don't know how much that really happens, but at least that is what I hear." Another geography professor explained:

I would say my department is really for it (faculty-student coauthorship). . . . My department considers multi-authored pieces to be as valuable as solo-authored pieces, which takes away any disincentive to work with students,

right? I mean, if solo author is more important, what are you going to put your energy into? You go off by yourself, pretty much. In my department, that is not how it plays, so that is a very nice kind of set up. Our tenure and promotion guidelines do not distinguish between solo and multi-authored pieces.

Faculty who had reached the pinnacle of their careers continued to respond to institutional expectations for publications through faculty-student coauthorship. For example, when asked if he published with his doctoral students, a full professor of statistics recounted:

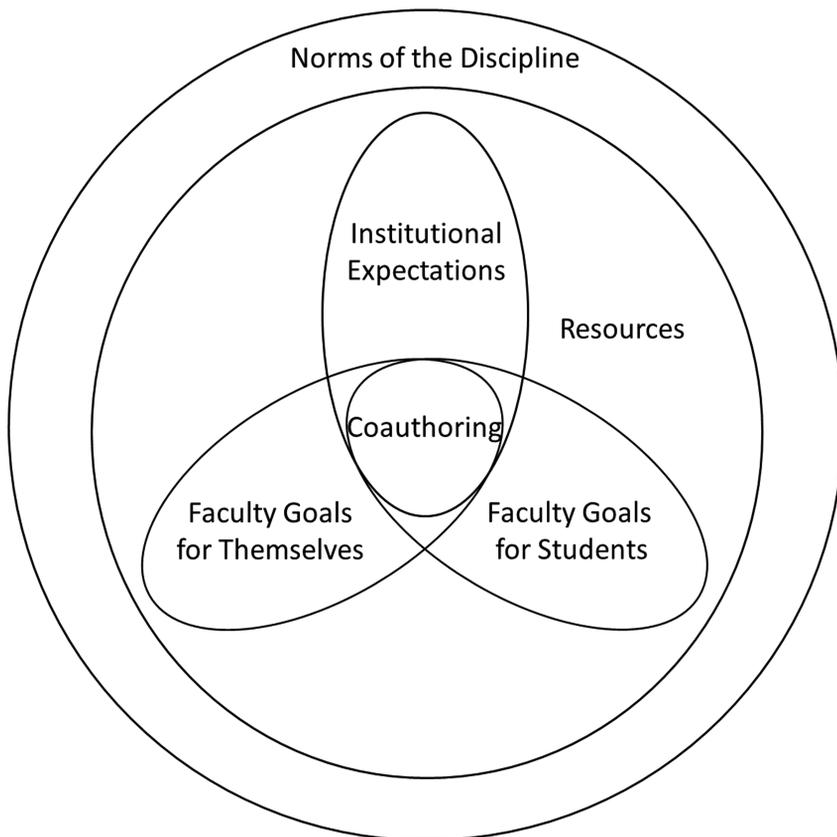


FIGURE 1. Interlocking Pattern of Factors Affecting Faculty-Doctoral Student Coauthorship

Oh, yes, always. That's a given. When we begin working together, that is what I tell them, a dissertation is . . . of publishable quality in the mainstream statistical literature. So, yes, there will be at least one paper and preferably two. I am never first author, even if I do most of the work, but my name will be there. It is not that I need it. I've got all my promotions and all that. I don't need any more papers, but yeah, my name is there.

Factor Overlaps and Intersections and Making "Good Progress"

It may be impossible to capture a full description of all possible linkages between the sub-facets comprising each of the five key factors articulated above. Variations across economic cycles, disciplines, institutions, and individuals overlap and intersect to create an ever-changing network facilitating or constraining faculty-student coauthoring. However, in the current study, broad patterns of interaction emerged. Each of the five main themes was distinguished from others by unique characteristics, and overlaps and intersections between them created an interlocking pattern that accounts for nearly all of contents of faculty narratives, as illustrated in Figure 1.

The borders of faculty-student coauthoring activity are shaped by norms of the discipline. STEM faculty are themselves socialized into coauthorship as doctoral students and postdoctoral fellows. They dutifully repeat this behavioral pattern with their own students. As an engineering professor relayed, "That [faculty-student coauthoring] is the way that it was always done with me when I was a grad student, so I have continued the way that I did with my advisor."

There is good reason that this tradition is handed down. Scientific inquiry, especially the interdisciplinary inquiry "necessary for attacking the most critical technological and socio-technological challenges facing the world today" (Borrego & Newswander, 2010, p. 61), is typically a labor-intensive endeavor. Tasks must be delegated and, as a chemistry professor observed, "If you want to make good progress, you have to do a lot of parallel processing and have people in the lab, so these would be your students." Successful delegation and parallel process requires a give-and-take of resources, primarily money, time, and talent. Without resources, disciplinary norms are not sufficiently supportive, and faculty-student coauthorship efforts may falter. As expressed by one math professor, without the resource of students with research and writing skills, writing "is just easier to do yourself."

Encased within the boundaries of disciplinary norms and resource availability are three tightly coupled factors. The words of the chemistry professor noted above—"if you want to make good progress"—have intricate meaning here. For most faculty, "good progress" is satisfy-

ing institutional expectations as well as meeting expectations for oneself and one's students. Conveniently, progress toward any one of these expectations often furthers progress toward the other two, depending on disciplinary norms and resource availability. In this study, making "good progress" in faculty-student coauthoring efforts moved faculty closer toward meeting (1) their institution's expectation that they socialize doctoral students toward publication, in part so that their institution is better represented within a particular scholarly community; (2) their own professional goals for promotion and increased status; and (3) their goals for students so that their students carry on their academic legacy.

Discussion

Learning to write as a scholar for one's discipline during doctoral training is critical for students with academic career ambitions (Nettles & Millett, 2006). The STEM faculty in this study clearly recognized the need for these students to establish a publication record. However, they deemed writing skills to be equally important for those who will join the burgeoning knowledge economy beyond the academy.

Many STEM doctoral recipients bypass academic careers (Nerad, Aanerud, & Cerny, 2004). In fact, Nerad and her colleagues reported that of those who participated in a national survey, only a fifth of electrical engineering doctoral recipients, a third of biochemistry doctoral recipients, and half of mathematics doctoral recipients desired a professorial position. As Austin (2010) observed, STEM doctoral education "can lead to a number of important careers, with academic work as one option" (p. 92). Regardless of the career selected, STEM doctoral recipients "will be writing for the rest of their lives" and must demonstrate mastery as a disciplinary writer.

In STEM disciplines, the critical task of learning to write as a scholar for one's discipline is often accomplished through faculty-student coauthorship. This study reveals five interlocking factors that dictate the context within which faculty-doctoral student coauthorship occurs: norms of the discipline, resources, faculty goals for students, faculty goals for themselves, and institutional expectations. These factors mirror many of those identified by Kezar and Lester (2009) as setting the stage for, commitment to, and sustenance of campus collaboration. For example, the influence of institutional expectations is well represented in both Kezar and Lester's work and our own. We found that expectations for a consistently high publication rate that includes faculty-student coauthored publications were communicated throughout the institutional leadership hierarchy. Incentives, rewards, and their influence on

collaboration were also well represented in the findings of both studies. Within our study, faculty carefully considered if, how, and when faculty-student coauthorship aligned with the institutional reward structure, and then acted accordingly. Finally, similar to Kezar and Lester's holistic stage model of collaboration in which each stage is intimately connected with all others, we found coauthorship to be nested within five interlocking factors, each which interacts with all others.

Kezar and Lester (2009) observed that "sustained change [to support collaboration] means rethinking overall organizational structures, processes and design" (p. 225). Our findings led us to agree, especially in relation to the concerns expressed about students' writing skills. As these faculty serve as tenure-track or tenured faculty at a large, research-intensive university, there is little reason to suspect that student skill level at this institution markedly varies from other institutions. These faculty—and presumably many of their counterparts at similar institutions—struggle to address doctoral student writing skill deficits.

Despite this challenge, faculty in this study appeared to realize that doctoral training entails preparation for scholarship, in which the developing scholar both conducts the research *and* writes the research. Thus, writing is not ancillary to research; it is "a vital part of the research process" (Kamler & Thomson, 2006, p. 3). Although it might be initially easier and faster to match lab duties to student strengths (e.g., those who excel at analysis are assigned to analyze, those who excel at writing are assigned to write), this type of matching ultimately undermines student development. While the relative distribution of tasks might have varied somewhat by current work demands in the lab, our participants seem generally mindful of their mentorship role and ensured that their students benefitted from a full range of experiences.

Areas of future research stimulated by findings from this paper abound. First, if faculty-doctoral student coauthorship is a key mechanism through which doctoral students develop into scholars, then what would facilitate an increased rate of coauthorship? As reflected by the number of coauthored publications presented in Table 1, faculty rank is related to frequency of coauthorship. However, even within rank, wide variations are apparent. Additional research may reveal ways to consistently raise the rate of faculty-doctoral student coauthorship at all stages of the faculty career to the mutual benefit of both faculty and students.

Additional investigation is also needed to determine how best to address the writing skill deficits perceived by many of our faculty participants. Maher et al. (2008) noted the surprising lack of explicit guidance for writing in doctoral education, observing the "tacit assumptions made

in universities regarding both the competence of students who enroll in doctoral degrees and about the pedagogical responsibilities of universities” (p. 264). Are faculty mentors the best people to shepherd weak writers on an individual, ad hoc basis, given their competing time obligations? Or should doctoral programs investigate mechanisms by which to make students’ acquisition of this skill a more explicit component of doctoral education? Adopting the latter position, Austin (2009) has outlined a pedagogical model based on cognitive apprenticeship in the form of a writing seminar for first-year doctoral students. She emphasizes making the criteria and processes involved in effective writing more transparent to students and encouraging reflection as a mechanism to develop both knowledge and metacognitive skills. This type of explicit instruction, embedded within department-level courses, may both address students’ writing deficiencies and free their doctoral advisors from providing this instruction on a time-consuming individualized basis. This approach may potentially lead to more frequent, productive, and less “painful” faculty-student coauthorship ventures.

We suggest that faculty-doctoral student coauthorship is a signature pedagogy (Shulman, 2005) of STEM doctoral education because it is both pervasive and routine. Coauthorship facilitates the measured transition from STEM doctoral student to STEM scholar in fundamental ways. It is surprising, therefore, how little we know about its structure, processes, time table, and outcomes. For example, if resources such as external funding and faculty research time affect faculty-doctoral student coauthorship opportunities, the implications for STEM doctoral students who attend institutions with lower levels of extramural funding and higher faculty teaching loads may be substantial. Further examination of this pedagogical strategy can provide valuable insight into strategies most likely to enhance the mutual benefits of faculty-student coauthoring.

Note

The work reported in this article was supported by a grant from the National Science Foundation, NSF-0723686. The views in this paper are those of the authors and do not necessarily represent the views of the supporting funding agency. The authors acknowledge the contribution of Dr. Christian Anderson in the initial development of the interview protocol.

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