

What Can We Learn about WID from Exceptionally High-Achieving STEM Majors?

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Abstract: This study reports on how a cohort of 16 especially accomplished undergraduate STEM majors narrate their literacy histories, experience learning to write in the sciences during their college years, and reflect on their priorities for writing more generally. These participants report largely positive early schooling experiences with writing; attribute progress in learning scientific writing during their college years more to the social networks of their undergraduate research labs than to traditional writing-intensive courses; associate “writing” more with personal agency than with assimilation to a disciplinary discourse community; assign more meaning to writing that is personal, narrative, public, and/or novel than technical; and believe that writing should serve multiple purposes, at once within and beyond their home STEM disciplines. Some of these findings disrupt the novice-to-expert assumptions of WID theory and suggest a latent demand for writing courses that depart from traditional technical communication and writing-in-the-major offerings.

One area at the nexus of STEM and writing studies that remains unexplored is how our highest performing STEM undergraduates negotiate their writing lives. This study opens that line of inquiry by focusing on a small and especially accomplished group of undergraduate STEM majors. These students are exemplars of emerging expertise who have apprenticed themselves to their chosen fields through stellar academic performance, sustained undergraduate research, aspirations to pursue advanced study in top graduate programs and medical schools, and successful disciplinary writing as manifest in honors theses and engineering design projects. Some are even co-authors on peer-reviewed articles emerging from faculty research labs, and all have either earned their university’s nomination for at least one highly selective national fellowship (Goldwater, Udall, McNair, National Science Foundation, Fulbright, Truman, Marshall, or Rhodes), been selected for a competitive on-campus undergraduate research program, or won a campus award for advanced writing in science and engineering.

If we understand the promise of WID to mean a movement along a trajectory toward authentic participation in a community of practice and relative fluency in the signature genres of a field, these students have fulfilled that promise, and well ahead of schedule. At the same time, their collective reflections, as expressed in interviews for this study, disrupt some axiomatic assumptions about WID, especially the notion that emerging scientists and engineers will, in the course of their schooling and professional development, incrementally align their values, identities, and writing practices ever more tightly with their chosen discipline. In contrast, most of this cohort resisted thinking of writing development as a progression from novice to expert in a particular scientific field. That finding runs parallel with what we learn from a recent longitudinal study of motivated STEM undergraduates at the University of Michigan (Gere, 2019). Like the participants in this study, the Michigan students profiled were clearly committed to mastering the

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genres and discursive moves of their STEM fields; however, both sets of students insist that writing is not only, or even primarily, about acquiring fluency in disciplinary or professional discourse.

Methods

This was an interview-based study of sixteen undergraduate STEM majors enrolled at the same public research university. Participation was limited to those who had been nominated by the university for prestigious national fellowships, chosen for internal university programs keyed to undergraduate research, or honored with a campus writing award in the sciences. All three selection processes were competitive and included rigorous vetting by faculty committees.

Forty-one students who met at least one of those criteria were invited to participate in two interviews about their writing histories and dispositions (and offered a \$50 gift card for compensation). 16 participants opted in: 12 seniors, one junior, three sophomores; ten women and six men; eight Asian-American, seven White, and one African-American. All eight of the Asian-American participants were multilingual, having grown up in families with parents or grandparents who were first- or second-generation immigrants to the United States and who spoke languages other than English in the home. The other eight participants were largely monolingual, although they had studied languages in school to varying degrees. While I did not ask specifically about social class, most participants shared that their parents were professionals who prioritized education for their children and involved them in academic enrichment activities. All were members of the university's honors program. All had substantial undergraduate experience in university research labs, and most had also participated in summer internship/lab experiences related to STEM. All planned to pursue graduate studies in the sciences, engineering, or medicine.

Most students in this group took on multiple majors and/or minors. In fact, only a quarter of them had a single major. Six had multiple majors/minors within STEM fields; six had extra majors/minors outside of STEM, including Anthropology, English, Philosophy, Psychology, Sociology, Spanish, and French. By design, this cohort was academically exceptional, which means we cannot generalize from their experiences to all STEM majors, but we can learn some things from these high-achievers that we might not learn from a more representative sample.

The first hour-long interview focused on personal literacy development from pre-school through the present. For the second, participants were asked to inventory all the writing they could remember from the previous semester, bring in one sample of writing that they thought represented them as a writer, and reflect especially on writing during their college years and in their futures (see Appendix for interview questions). The interviews were recorded, converted from audio to text by a software system, then reviewed for accuracy.

The transcripts were sorted by question; that is, the text of all sixteen responses to a given question were loaded into a separate spreadsheet column, and each set of aggregate responses was reviewed and coded. Some questions employed simple coding schemes. For example, each of the narrative responses to "How do you think writing and communication will figure into your future as a ___? Can you estimate how more or less important, and in what ways?" was coded as "not at all important," "moderately important," or "very important," based on the student's use of similar language and/or my interpretation of their response. Other questions required a grounded theory approach to developing codes after an initial review of the transcripts. For example, for the question that asks who was significant in their writing process in college, mentions of individuals were coded as "college instructors/professors for courses in STEM discipline/major," "college instructors for course outside STEM major," "faculty PIs in research lab," "grad students in research lab," "thesis advisor," "national fellowship advisor," "family members," and "friends/peers" because those were all mentioned by participants. Some codes required more interpretation, such as discerning when students, while reflecting on a sample of their own writing, were either tacitly or explicitly discussing their purpose as writing to learn, writing to reflect on their identity formation, writing to communicate, or writing to meet

disciplinary conventions. Not all of the transcript texts were segmented and coded; instead, only those parts that seemed most significant were coded and then tallied for frequency. The aggregated transcripts for each question were also reviewed using more intuitive thematic and typological analysis (Green, 2008). The author alone did the coding, analysis, and culling of representative passages from the transcripts.

Results

What follows are the most salient findings from an analysis of the thirty-two interviews. The analysis revealed intriguing patterns in how students reported their literacy histories and attitudes, how they expressed tacit definitions of writing, where and how they developed as writers, and what they value about both scientific writing and writing more generally.

Personal Literacy Histories: Science People, Yes, But Also Inclined to Writing

Lisa Emerson (2019) has, perhaps more than any other scholar, documented the attitudes that students of science have about writing, and what she reports is rather disheartening:

Years of schooling have provided them with negative self-efficacy as writers and used models of writing that promote beliefs of writing and science as, at best, disconnected and of knowledge making in science as divorced from the process of writing, leading to a consequent belief that there's no reason to expect them to learn to write science. (p. 177).

Her interviewees report mainly negative—some even traumatic—experiences with writing instruction during their primary and secondary schooling. Emerson (2016) finds that things generally do not get much better in college: “[F]or the majority of participants, the undergraduate years were equally devoid of authentic opportunities to engage as writers of science or to adjust the attitudes and beliefs about writing they had acquired as children” (p. 203). These conclusions run decidedly counter to the literacy histories of participants in the current study: nearly all identified their preference for science as emerging early in childhood *and* reported rich and largely positive experiences with writing throughout their personal and schooling lives.

For all but one of sixteen, their earliest memories of writing were warm and positive, and for more than half, very positive. They composed stories, poetry, letters and journals for themselves or their parents. A few wrote “books” about themselves or family vacations or animals and imagined themselves future authors even before imagining themselves as future scientists, doctors, or engineers. When they narrated their experiences of primary school, a minority bristled at the rigidity of timed writing tests, the tediousness of lessons in handwriting, or the capriciousness of some teachers, but the majority had affirming experiences with language arts and other writing-intensive subjects in school—and often outside of school as well.

Keep in mind that these future fellowship nominees had always been strong students across all subjects. They were eager early readers and teacher pleasers, and most came from either middle class or striving first-generation immigrant families with parents who explicitly prioritized reading and writing. They attended well-resourced schools with robust literacy instruction. From the beginning they experienced school as a place that affirmed their academic success across the curriculum. While all imagined futures in the sciences or engineering by middle school or earlier, that did not come with a corresponding distaste for other subjects. That is, they did not experience the bifurcation that Emerson’s participants report: a growing sense of competence in math and science paired with a corresponding sense of deficit, disinterest, or even shame in language arts.

As this cohort moved through high school, their math and science preferences solidified and most—though certainly not all—grew increasingly skeptical of the typical approaches to close reading and literary criticism that they experienced in English courses year after year. Yet they were still good at playing that game, even when it did not intrinsically motivate them. Moreover, nearly all pointed out especially inspiring and/or challenging teachers of English and history who opened opportunities for thinking creatively and exercising personal voice in writing, which they particularly appreciated. Several were part of either summer or year-round extracurricular science enrichment/research programs, often involving reviewing scientific literature, doing labwork, presenting, and writing.

While by college several participants did not enjoy writing, none perceived it as irrelevant, and none went to great lengths to avoid it. All expressed relatively healthy self-efficacy, even if some had more confidence in their writing abilities than others. A majority were also deeply interested in humanistic questions of culture, politics, philosophy, identity, personal expression, and social justice, interests that they carried forward into college (recall that six elected additional majors or minors in the humanities and social sciences, and even those who did not expressed appreciation for at least some of their writing-intensive general education courses).

This cohort defies the “I’m a math and science person; I don’t like humanities/writing” caricature. They clearly are science people, but they didn’t bear any scars from past literacy instruction, and there was no need to persuade these well-rounded high-achievers that writing is important to their futures as scientists and engineers, although those planning to become practicing physicians anticipated that writing would be less central to their professional lives than those anticipating careers in research, engineering, and academia.

College Years: Little Feedback in STEM Courses but Lots of Learning in the Lab

I asked participants to narrate their writing development during college so far, highlighting experiences that they thought most significant. I also asked them to do an inventory of their academic writing assignments from the previous semester (we went course by course) along with any other significant writing that they did (graduate and med school applications, fellowship applications, tasks for extracurriculars, personal writing, etc.). I followed up those with a series of more pointed questions about their experiences with writing assignments in their STEM courses; their typical writing process; what their most difficult writing challenge has been; and what they believe to be their most meaningful and most difficult writing to date. Here are the most relevant patterns that emerged:

- These students were doing substantial academic and co-curricular writing. None produced fewer than 20 manuscript pages the previous semester; several generated well over 100 pages (and these are likely underestimates because I counted only what they could recall on the spot). Even the seniors who were enrolled in all advanced science and engineering courses were writing a fair amount in those courses; meanwhile seniors were composing honors theses or collaborative senior design projects. Those with additional majors and minors in the humanities and social sciences were doing still more writing. Most were doing further writing keyed to their undergraduate research labs, and most were devoting serious time to drafting and revising graduate, medical school, and/or fellowship application materials. Much like students documented in the Stanford study of writing, many were also doing ample co-curricular writing, such as projects related to extra-curriculars and campus activism (Fishman, Lunsford, McGregor, & Otuteye, 2005).
- How they reported their inventories revealed that most defined “writing” in ways that align more with personal agency than disciplinary norms. While doing their inventories, for example, several of the seniors would say something like, “OK, Bio-Chem, no writing there,” and I would gently interrupt, saying, “So no lab reports?” And then they would say, “Well, actually yes, we had

weekly lab reports,” then together we would add those to the inventory. After this happened a few times, I started asking students why they did not register such lab reports as “writing” until prompted, and they would reply that those were “just, like, checking boxes” (though in fact they were typical lab reports comprised of text and figures) or that they had done them collaboratively in small teams. Most did not see such tightly constrained reporting and discussion of results, or collaborative writing, as “really writing,” which is curious because from a traditional WID point of view, such habituated, naturalized mastery of the lab report as a genre and a comfort with co-authoring processes should be signs of growing insider status or maturity in scientific writing (Bawarshi & Reiff, 2010; Russell, 1997; for pedagogical alternatives to lab reports, see Alaimo et al., 2009, and Rhudy, 2019). Yet these participants intuitively defined “writing” in somewhat romantic terms, associating it more with personal agency than with assimilation to a disciplinary discourse community.

- They testify to learning more about technical and scientific writing from interactions in their research labs and other out-of-class research projects than from regular classroom instruction, including those courses explicitly labelled as writing-in-the-major. Among the participants who had experience with the same lab for more than a year, all reported getting more feedback in that lab as compared to in their STEM courses. In their lab research roles, participants interacted regularly with graduate students, peers, and faculty PIs. When their writing circulated in the lab—literature reviews or summary reports that were required at the conclusion of summer internships, drafts of technical proposals that were required for fellowships like the Goldwater, drafts of conference posters—they reported receiving prompt, specific, contextualized—and often blunt, and occasionally bruising—feedback from graduate students or faculty mentors. As one senior biomedical engineering major and Goldwater fellowship winner put it:

I guess what I feel is that, in the end, within the engineering school, we are required to write a lot, but they don't often grade us based on our writing abilities. They grade us on the information that we're presenting, and if it relevant...It would be nice to get feedback on my actual writing and how well I'm communicating the ideas rather than just the ideas themselves, and I feel like I haven't gotten that in school...I do feel like I've have gotten that through like my academic writing in the lab, but not so much in coursework.

Another participant, a senior genetics major and nominee for a Mitchell fellowship, reflects:

I mean, I honestly don't think I learned it [how to create a coherent storyline in my research writing] in the curriculum. I learned it from J___, who was also one of my professors [and the mentor for her senior thesis research], but I think just [I learned] more through the process of writing something like my U Scholar proposal [an internal university honor], so like, it's definitely there...but she wasn't my W [designated writing-in-the-major course] professor.

Given that these students have travelled through a WID curriculum with a required writing-in-the-major course, it is surprising that so few found that course a significant touchstone. On the other hand, given what we know about immersive experiential learning, perhaps it is not so surprising (Bazerman, 2021; Cole & Griffin, 2013; Hull & Schultz, 2001; Lave & Wenger, 1991; National Research Council, 2000).

- When facing challenging writing tasks, they turn to networks of people—not books, not Internet resources, not models, not writing centers. None of the participants owned a writing guidebook and most were somewhat perplexed at even the suggestion that they might use one. None

regularly consulted discipline-specific writing resources on the Internet either, and only a few visited a writing center or sought out models/samples when faced with a new task (as both a writing center director and a series editor for a set of discipline-specific writing handbooks, that was an eye-opener). But it also became clear that these students had another ready resource: they turned to people, and the most significant people in their writing process were the faculty PIs in their labs, the graduate students in their labs, the national fellowship advisor at their university, and family members. For students who start doing lab work early, as many in this cohort did, the lab community can be transformative for their writing, as it was for this triple major in biology, anthropology, and Spanish:

In lab was the first time I was forced to do revisions. And when I first got it back, it was red everywhere, and I was like, "What?" I had submitted to my PI directly, and he was like, "That is not how we do it here. You never submit your draft to me directly. You have to go through the grad students, and then they'll tell you," and I was like, "Okay." And that was freshman year. So after that, I saw how good it got afterwards, how much better. And I was like, "I should be doing this for a lot of other stuff as well." And so I got more comfortable with that.

This participant also remarked on how "at home [it was] a little more difficult because for my parents English isn't their first language, and my brother is not an English person either, so I didn't know who to ask at home."

- They report getting little feedback on writing in STEM courses, even courses that are explicitly labelled as W/writing-intensive. While some students highlighted instructors who offered substantial, personalized feedback, those were the exception. Most reported that in regular STEM courses, faculty and TAs offered minimal or no commentary on the rhetorical aspects of their writing. All of them wanted more feedback. Most reported that their writing garnered more personalized attention from humanities and social science faculty.
- Composing processes for regular classes differed from composing processes for sustained labwork and fellowship applications. When writing lab reports and other IMRD genres for regular classes and lab sections, nearly all started with the introduction and marched through in IMRD order.¹ They perceived such assignments as constrained enough to handle in a linear manner—that was most expedient for them, and good grades followed. But for their lab-based writing, only a few started with the introduction first; most instead began with figures, results, methods, the literature review, or a mess of notes—or, in co-authored projects, with whichever section or figure had been assigned to them (a few still did begin with the introduction but saw it as a placeholder that they would need to revisit). A materials science student who was aiming to publish a paper based on her senior thesis research describes her process:

Dr. H____ just said, "Okay, write the paper, and then bring it back." And so I wrote it [like I usually do for school] and then he was like, "Okay, this, this, this, and this is all wrong. This order is wrong, blah, blah, blah, you should have actually started with doing the figures first, and then constructed the paper off of that." So then I had to go back and throw out everything I did. And then I started with the figures afterwards and wrote the paper around that and in that like, typical style, I guess. That was definitely different. And I haven't been required to do that for any of my courses.

The authentic lab, research, and fellowship writing tasks were far more challenging, unfamiliar, and ill-defined, and those often disrupted default school-based processes, inviting—or forcing—more recursive and social modes of composing.

- Writing as part of the fellowship application/nomination process proved especially intense and formative. At many institutions, including the one these students attended, the national fellowship application process involves extensive coaching in both writing and interviewing. The director of the fellowships office, who holds a PhD and faculty credentials, albeit not in STEM, works individually and intensively with each candidate to help them craft personal statements and other materials. This happens both during internal university vetting processes for fellowships that limit the number of nominees the institution can put forward, and again during the period between when nominees are selected but have yet to submit final applications. One biology/sociology major who was nominated for several major fellowships described her process:

Dr. M_____ helped me a lot when I was writing my scholarship applications. And it was really through that iterative process of going back and forth with him, and he being like, “Nah, this doesn’t really tie together—like what is your purpose? What do you want to do?” Because my interests are so disparate, and I never actually took the time to step back and be like, why am I doing all this stuff? Like, I’ve done everything I love. I’ve never not followed my heart, but like, why am I doing this? What’s the purpose behind it? So I think the personal statement was the most meaningful [thing I wrote in college] because it really took a lot of soul searching to get there.

A molecular and cell biology major likewise describes composing his Truman Fellowship application essays across multiple drafts, spurred on by candid response from that same advisor:

And sometimes I just completely scrapped them. Sometimes I thought I had like a really good passage written up, and I showed it to Dr. M_____, and he was like, “Nah, you gotta scrap this dude.” So it was really challenging. And it was the most in-depth—and revision-wise the most in depth—I’ve ever done for any writing.

Feedback was keyed not to scientific genres, STEM disciplinary values, or technical style but instead to the particular expectations of the narrative personal statement. As I will discuss later, many participants found this writing—and the interactive process by which it was generated—especially meaningful.

The Things They Carried (Into My Office)

In advance of second interviews, I asked participants to either email me or bring with them a text that represents them as a writer. I told them that it could be from a course or not. I noted that if they really couldn’t settle on one document, they could bring in two.

Prevailing WID assumptions over the last forty years (Bazerman, 1981; Berkenkotter, Huckin, & Ackerman, 1988; Geisler, 1994; Haas, 1994; Beaufort, 2007; Poe, Lerner, & Craig, 2010) might predict that participants would select the sample of writing that reflects their emerging insider status as a researcher/writer in their chosen discourse community—for example, a paper from an advanced or capstone course in their major, a senior honors thesis or engineering design project, the research proposal section of a Goldwater or National Science Foundation fellowship application, a publication on which they are a co-author, and the like. In fact, only three of sixteen participants elected to bring a single sample of their most technically sophisticated and discipline-specific STEM writing.

- A plurality—seven participants—brought in one such piece of STEM writing *and one additional piece*, with five of those being fellowship/graduate/medical school application personal statements, one a philosophy paper, and one a poem.
- Two more brought in one piece of STEM writing, but ones adjacent to their majors or primary research areas: a molecular and cell biology major brought in a literature review from a recent biochemistry writing-intensive course, and an engineering student brought in a final report/paper from an NSF-funded summer research undergraduate experience in stem cell research (she had written it two years earlier and had since pivoted to materials science engineering).
- Four brought in only texts that were not scientific or technical. These included a graduate school personal statement, a college application essay (one of the two sophomores in the study), a Truman fellowship policy proposal (the Truman is keyed to public service, not scientific research, and this proposal did not have a STEM dimension), and a public-facing blog post on cryptography written as part of a summer internship with a cyber security firm.

I asked participants why they selected their texts. That largest group of seven that brought in one STEM genre and one non-STEM genre offered variations on the same theme: the disciplinary writing was important to them but could not alone, or even primarily, represent them as a writer. Most held fast to associations of writing with self-expression and personal agency, and they saw less room for self and agency in scientific and technical writing as compared to their academic writing for the humanities and social sciences, their personal statement writing for graduate and fellowship applications, and their non-academic personal and public writing. A senior civil engineering student captures the tenor of how many framed the writing they do alongside their STEM courses and lab research:

I think, like in the past year or so as I've developed more of an interest towards social justice and trying to incorporate other dimensions of study into what I'm interested in, I've gotten a lot more passionate about getting better at writing to, and I think realizing that writing is so important to convey messages, like get people behind a certain idea, has made me realize that that's something that I really want to get better at, especially having seen people writing articles about their ideas—like getting put in the *Daily Campus*, or like things like that, I think is more inspiring for me to try and put what I'm thinking or certain ideas I have on paper, to be able to share them.

This senior brought in a poem along with an engineering lab report; during our interview she also pointed me to an article she had published in an online venue, composed “mostly just for me and my friends,” about a sexual assault that she had experienced as a first-year university student and how that shaped her current perspective on consent. She perceived real value in both her sophisticated engineering writing and her decidedly non-STEM personal and public writing.

This emphasis on the heterogeneity of student literacy practices would not surprise Kevin Roozen and Joe Erickson (2017), who question the “dominant maps” of socialization into disciplinary writing conventions as they carefully document the diversity of textual practices—personal, academic, artistic, professional, and otherwise—that constitute the larger literacy landscapes of their student participants and how those cumulatively shape even their disciplinary and professional writing. These and similar studies (Prior & Shipka, 2003) account for how such lifeworlds get “recruited into disciplinary activity” (Roozen & Erickson, 2017, chapter 1.04).

In their retrospective reflections about how they came to be strong scientific writers, participants in this study generally resisted acknowledging such developmental connections to their personal, creative, and/or public writing, and often even transfer from their first-year composition and general education classes, which doesn't mean such connections weren't there, only that my questions and methods did not render

them visible. However, in their prospective reflections, and especially in the discussions of their writing samples, they tended to insist on multiple purposes and priorities for writing, both personal and public, ones that diverged from the purposes and priorities of the scientific writing they associated with their major fields. In this sense their attitudinal patterns were uncannily resonant with findings from the cross-disciplinary, longitudinal study of writing across the curriculum that Anne Ruggles Gere (2019) led at the University of Michigan.

One strand of that study features case studies of STEM majors, and as Ryan McCarty (2019) profiles an especially talented student, he notes that “there is very little evidence that she would agree with conventional wisdom about writing development that tends to focus on students’ abilities to move from novice to expert status in one distinct academic context.” He goes on to confirm this pattern as pervasive: “this kind of target-language assumption, in which students see their writing development as a striving to develop unmarked fluency in one disciplinary academic language, was simply not what we were hearing from some participants or seeing in their writing.” And further:

[T]he students...are not discounting the importance of learning the languages and styles of their respective disciplines...However, their understanding of how and why they develop writing for particular purposes is centered not on a single way of posing and solving problems, but on the incorporation of knowledges and writing conventions from across many contexts. These students speak of themselves and their writerly exigencies as spanning many intellectual, personal, and future-professional spheres, and while they often acknowledge the need to conform to particular expectations at times, they see their most substantial moments of writing development in cases when they draw from across a wide repertoire of writing resources.

Another indicator of the inclination toward this wider repertoire is evident in how these students have taken on multiple majors and minors, whereas early WID theory came of age under the presumption that students would develop progressively within a single major/discipline.

In *Engaged Writers and Dynamic Disciplines*, Christopher Thaiss and Terry Myers Zawacki (2006) argue that disciplines are more diverse and dynamic than we might presume. But participants in this study, like those in the University of Michigan one, were not itching to widen disciplinary boundaries. For these undergraduates, that prospect did not come up because, I think, they didn’t, as undergraduates, feel that they had the agency to change a STEM discipline. Instead, they insisted that their own personal writing development is happening, and should be happening, on multiple fronts, spanning multiple purposes and genres, at once within and beyond their disciplines.

What’s Difficult, What’s Meaningful, and Why

Inspired by the *Meaningful Writing Project* (Eodice, Geller, & Lerner, 2016), I asked students to name their most meaningful writing to date. The surprise here, much like the surprise of the writing samples they chose to represent themselves, was that only five of sixteen identified a most-meaningful text that aligned with the “target-language assumption” of WID—that is, one that represents the most conventionally mature scientific writing they have done in their discipline, such as a senior thesis, a publication, a research paper from an advanced writing-intensive course, or a technical/research part of a fellowship application. Most participants reflexively seemed to hear “meaningful” as “personally meaningful” rather than “professionally meaningful.”

Of the eleven who named something outside the signature genres of STEM, four pointed to narrative personal statements for graduate school or fellowship applications. Here are the reflections of a senior materials science and engineering major and Goldwater fellowship nominee:

The personal statement for was the most meaningful that I've written so far, in that integrating it helped me reflect and redefine my actual personal goals and moving forward in graduate school...As for scientific writing, I like it as a communication method to explain my research to others, or like, whatever I'm doing, to get the communication out. And it should be clear and concise. But in terms of meaningful to me, I think personal statements are more like describing who I am, and that would always be more meaningful to me.

Similar reflections across the interviews reminded me that while these undergraduates were, in their STEM lives, performing much like graduate students or mini-professionals, they were still very much in their early twenties, persons in process (Herrington & Curtis, 2000), figuring out who they are. They seemed to be craving more such opportunities to use narrative forms to explore themselves and their future selves.

Three others identified their most meaningful writing as papers for non-STEM classes in philosophy, anthropology, and English, all fields in which those participants were also double majoring or minoring. Three other participants singled out public writing: a high school graduation speech, a series of blog posts, and the online article about a sexual assault referenced earlier. One pointed to a final paper for a summer internship completed two years earlier, which was in a subfield she had since pivoted away from—indeed, she was doing much more sophisticated research and writing in her current major, but she named that paper from two years earlier because it marked her first substantial foray into scientific writing.

Most attributed meaningfulness of their chosen texts to one or more of three factors: (a) those opportunities afforded them more personal agency than the typical writing they do for school, including their STEM major; (b) in the process of composing them, often across multiple drafts while getting feedback from a teacher or mentor they respected, they were actively learning about something and/or themselves; and (c) the writing was simply different from what they usually do, and they persistently associated novelty with meaning. That final point about novelty is mirrored in the Meaningful Writing Project, in which Eodice, Geller, and Lerner (2016) found that 79% of students declared not having previously written something similar to what they selected as their most meaningful text.

Writing expertise in a discipline comes from progressively more challenging practice in the same few signature genres of a given discourse community, and much of our thinking and curriculum-building in WID takes that as its governing principle. A minority of students in this study hewed to just such an ideal, as evident in this remark by a senior material sciences major:

I see the writing as, like, the center of the sciences because I think the science is useless if you're not able to disseminate your work in an understandable way. Okay. So I think that's kind of like the, the writing isn't the point. The science is the point. But they're so intertwined, that sometimes I think they become like the same thing.

However, most of the high-achievers in this study persistently attributed meaning not only to the writing emerging from the discipline in which they had invested so many years of effort to enter, and to which they were planning to further apprentice themselves through graduate study, but also to writing outside their home disciplines, done in genres or for audiences that were new to them. That “both/and” pattern, when viewed in light of these students' inclination to take on multiple majors and minors, and the corroborating findings from the University of Michigan study and The Meaningful Writing Project, suggests to me that our enthusiasm for a novice-to-expert or periphery-to-center conception of WID has perhaps gone too far. It's not just that such a conception misses too much (Roozen & Erickson, 2017), but that it can steer us away from the reformist, write-to-learn priorities of the early WAC movement (Mahala, 1991), which encouraged experimentation with a wider variety genres and put a greater emphasis on the intersections of academic learning and self-expression.

Discussion & Implications

While all this leaves me questioning the idealized novice-to-expert trajectory of writing development in one discipline that is presumed in much WID theory and curriculum development (for similar lines of questioning see Villanueva, 2003), we need to be careful about generalizing based on the dispositions of sixteen exceptional students who are privileged enough to have access to rich, authentic, multi-year undergraduate lab research experiences—not to mention intensive fellowship application coaching—to which they attribute so much of their growth as writers. In sobering contrast, Emerson found that for most of her participants, “the undergraduate years were...devoid of authentic opportunities to engage as writers of science” (2016, p. 203).

This may lead us to the somewhat obvious and idealistic implication that universities should channel STEM students into early, authentic, and progressively more intense undergraduate research experiences that stretch well beyond traditionally structured lab and WID courses, and even go beyond the high impact practices we typically associate with improving college writing curricula (Boquet & Lerner, 2016). Some elite universities and liberal arts colleges, as well as many honors programs, require all their STEM majors take up the kinds of original undergraduate research and help them land rich summer internships of the sort that participants in this study experienced.² Ideally, this should be the norm rather than the exception, and in that ideal world, the site of learning to write in a scientific register would—if the patterns in this study cohort hold—shift from the traditional curriculum to the activities and social networks of the research lab. Of course the haunting ethical question here is that the very students who could benefit most from such sustained, authentic learning environments may be the ones most likely to be left out while institutions double-down on amplifying the advantages of a small slice of honors students and nominees for prestigious fellowships.

A final implication concerns what these sixteen future STEM leaders seem to want from the writing curriculum but are not finding—and here I am mostly interpolating from the collective data rather than reporting on what they said they wanted, even though sometimes participants, like this biology major, were direct about this: “In terms of scientific writing, most of my stuff that I’ve learned was through my lab. But in terms of if I *want*, I would definitely love to learn more about like, legislation writing, okay, policy writing—that’d be really cool.” Most participants in this cohort reported not wanting additional WID or technical communication courses, although they universally craved more feedback from STEM faculty in the courses they already have; nor did they show an appetite for humanities courses that prioritize close reading. The most prominent absence in their curriculum seemed to be opportunities for generating meaningful writing as they define and experience it. For this constituency there is, I think, a latent demand for courses and assignments keyed to narrative, life writing, identity, ethics, and public writing that might be met with upper-division electives such as creative non-fiction, medical humanities, and interdisciplinary approaches to public policy and social justice. Moreover, given the persistent link between meaningfulness and novelty, we might encourage greater experimentation with genre both within and beyond their disciplines.

Appendix: Interview Questions

Interview 1 [45-minutes]

1. What is your year at X university and your major?
2. What is your native/home language or languages? Do you speak and/or write in additional languages as well?
3. Could you share when you decided on your major and what led you to it?

4. Now we're going to jump way back in time: What are your earliest memories of writing? They could be from home or school.
5. Could you trace your development as a writer and share a few of your most formative experiences of learning to write in elementary, middle, and/or high school? These could be positive or negative.
6. Think back to when you were leaving high school: what do you think you could say then that you knew for sure about writing?
7. How well do you think that English courses in high school and college have prepared you for the writing you've had to do in STEM courses?
8. Could you now trace your development as a writer during your college years? Follow-ups: Did you take FYW here? Tell me about that and other courses that included significant writing. Any other important factors, people, experiences?
9. How has your writing changed, if at all, during your college years? Has your writing process changed at all?
10. Were any individuals—teachers or not—particularly influential to helping you write more generally? And how about writing specifically in STEM?
11. What is the hardest thing you've had to write so far (could be for school, work, lab, or applications)?
12. What is the most meaningful writing you've done during your college years?
13. [If time] Could you talk about your writing process for formal assignments and projects? What guides your thinking and your practices? Any notable strategies or habits you have when you write?
14. What do you think you still need to learn about writing during your college years, if anything? And what about for beyond college?
15. For our next interview, you should bring in one piece of your writing, something that is either meaningful to you or representative of your writing in STEM. It can be something old—from earlier in college or even from high school--or something current that you are working on in classes now. It could be from one of the experiences we have already discussed. What might be some possibilities for that?

Interview 2 [45-minutes]

1. Think back to our last meeting when we discussed your personal and academic history with writing. Since that meeting, have you thought of anything that you want to add?
2. Think back to last semester: Can you do a quick inventory of how much did for your courses? [This also involves estimating page counts] And how about for other purposes — labwork, job, grad school or fellowship applications, clubs, personal or creative purposes?
3. For today's meeting I asked you to bring in a piece of your own writing. Please show me what you brought and explain why you chose this particular piece/s.
4. How does this piece/s relate to other writing you have done and are doing now? [Consider it both in courses for your major and other courses. Both for school and outside of school assignments.]

5. What do you think this piece says about you as a writer?
6. Can you describe the process by which you composed this? Start with pre-writing—what you did or thought even before putting pen to paper or fingers to keyboard and chronicle the process right up through the final version, as best you can remember. Even include contextual factors, such as where you wrote it and who else, if anyone, was involved in the writing process.
7. Can you point me to one or two passages in your sample that are typical of your style? Guide me through those as best you can and let me know what you were thinking, as best you can reconstruct.
8. Are there any resources (books, websites, writing center, etc.) or people that you typically turn to/return to when you do writing for your courses, thesis, or research lab?
9. Let's talk about the university curriculum for a few minutes: What do you think are the best ways that curricula or other kinds of writing initiatives should be structured? How well did you think your W [writing-intensive] course in your major worked [if they have taken it already]? Do you think there should be more technical writing courses required, or other kinds of writing courses required or available? How about possible approaches not structured as formal courses—what might those look like?
10. Looking ahead, what more do you think you need to learn about writing, if anything? Are there any other goals or aspirations you have for your writing or communication that we haven't discussed already?
11. Can you remind me of your career plans, both for the years immediately following college and for the long term?
12. Let's assume those plans work out. How do you think writing and communication will figure into your future as a _____? Can you estimate how more or less important, and in what ways?
13. Is there anything else we haven't discussed but that you think is significant?

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Notes

¹ Several years ago, when working with Leslie Ann Roldan and Mary Lou Pardue on *Writing in Biology*, those co-authors proposed departing from the traditional sequencing of scientific writing guides—that is, taking Introduction, Methods, Results and Discussion sections in turn. Pardue and Rolden wanted to put Results earliest because that is where practicing scientists usually begin. So that’s what we did. This came to mind as I was listening to students report that their undergraduate research and fellowship personal statements rarely matched the rhythms of the semester, went through more drafts, circulated more recursively than anything they did for regular classes, and often had different starting points. This prompted me to add a follow-up question about sequencing to later interviews: Which section do you usually start with?

² And why stop at STEM majors? Listening to students speak of their intensive labwork made me acutely aware of the paucity of such experiences in the humanities, where undergraduate majors have less access to lab-like spaces in which faculty, graduate students, advanced undergraduates and novice undergraduates inhabit the same busy research space, interact in various permutations over spans of a year or more, and circulate texts. Non-STEM students also have fewer opportunities for funded summer research internships.

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