STEM Faculty Focus Groups Respond to Student Writing and Learning Goals: Entry Points and Barriers to Curricular Change

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Collaboration between WAC practitioners and disciplinary faculty on the development of writing goals helps center field-specific expertise and build long-term investment. However, the tacit nature of writing knowledge in STEM presents challenges. We provide a snapshot of such challenges through faculty focus groups conducted in three departments (civil and environmental engineering, crop sciences, and physics) that aimed to surface tacit knowledge, gain insight into disciplinary writing values, and promote conversations about the integration of writing across a curriculum. Faculty responded to student writing by evaluating students' scientific becoming and occasionally co-constructing process narratives. In contrast to the specificity and variety of their expectations regarding student writing, faculty largely expressed agreement on a preliminary set of writing goals. We found that (1) faculty experiences integrally shape curricular conversations, (2) instructional barriers (e.g., time, labor) can lead to the persistence of generalized conceptions of writing, and (3) the focus groups revealed the difficulty of translating writing expectations into concrete curricular changes.

Introduction

Building long-term pedagogical investment in writing requires surfacing the rich literate[1] histories and tacit knowledge of disciplinary faculty while differentiating that knowledge from limiting assumptions about writing and student writers (e.g., Anson & Dannels, 2009; Bohr & Rhoades, 2014; Flash, 2016; Hughes, 2020). Curricular

1. We use the term "literate" in reference to our use of Paul Prior's (1998) framework of "literate activity," an approach that moves beyond material texts to view writing as situated, mediated and dispersed. According to Prior, literate activity "is not located *in* acts of reading and writing, but *as* cultural forms of life saturated with textuality, that is strongly motivated and mediated by texts" (p. 138).

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change requires faculty to adopt a process orientation to writing (Kovanen et al., 2020), recognizing that disciplinary writing cannot be fully addressed in a single class but requires continuous, situated practice within students' fields (e.g., Crowley, 1998; Jamieson, 2009; Kerri, 2017; Melzer, 2014; Rhoades & Carroll, 2012). As a six-year transdisciplinary, writing-across-the-curriculum (WAC) team with members from engineering, the sciences, and writing studies, we aim to build writing goals situated within STEM departmental expectations, interrogating faculty ideologies around writing and identifying barriers to curricular change.

Our work as a team began with a needs analysis of engineering curricula at our institution, the University of Illinois Urbana-Champaign. We found that students in engineering departments frequently place out of first-year writing courses (60 percent in Fall 2016) and, aside from fulfilling an upper-division composition requirement, primarily encounter writing instruction in laboratory or design classes toward the end of their curricula (Yoritomo et al., 2018). Engineering curricula at our institution are heavily influenced by criteria set by ABET, including "an ability to communicate effectively with a range of audiences" (Accreditation Board for Engineering and Technology, 2023), but this wording is sufficiently vague that it cannot really guide instruction. To address these gaps, one of our ongoing initiatives is to vertically integrate writing instruction across all four years of undergraduate STEM curricula.

In this paper, we focus on one stage of this work: faculty focus groups conducted in three departments (civil and environmental engineering, crop sciences, and physics) with the aim of building learning goals around writing in STEM. Through these focus groups, we sought to surface faculty knowledge around disciplinary communication and build investment in shared writing values. We reflect on the disciplinary expectations and challenges in developing writing goals that these focus groups revealed, offering implications for other WAC stakeholders.

WAC/WEC Models for Constructing Writing Learning Goals

To inform our approach, we looked to other WAC programs that construct writing learning goals with faculty. Such programs emphasize the importance of centering faculty knowledge, maintaining departmental pedagogical agency, and situating writing studies researchers as catalysts for change. These principles were recently united by Chris Anson and Pamela Flash (2021) in a writing-enriched curricula (WEC) model. WEC programs position writing as central to learning, implement "ongoing, partnered support," view tacit understandings of writing as hugely influential in writing instruction, and seek to build meaningful integration of writing into curricula through sustained questioning of "assumptions and expectations" (p. 20). WEC literature reinforces the time and resource investment necessary to build

change. In this paper, we respond to the need for more discussion of the initial stages of this long-term, resource-intensive process.

For example, the communication-across-the-curriculum (CAC) program at North Carolina State exemplifies WEC values by giving departments complete control over their response to formative reports profiling the placement of writing in department curricula, and by centering faculty voices throughout these conversations (Anson & Dannels, 2009). Similarly, a WAC offering at the University of Wisconsin–Madison, integrated as a unit within a year-long faculty professional development program, emphasizes articulating "discipline-specific rhetorical knowledge" over "converting uninitiated colleagues" (Hughes, 2020, p. 54). Faculty self-select to join the program and, as Bradley Hughes (2020) noted, articulate a rich range of pedagogical writing goals. At Wisconsin–Madison, taking up a WEC approach means accounting for these goals while also acknowledging possible limitations in faculty's conceptions of writing.

The University of Minnesota's WEC program provides another example of challenging writing ideologies through ongoing conversations in which faculty are empowered to make change in their departments (Flash, 2016). Pamela Flash (2016) outlines the role that writing studies researchers and WAC stakeholders can play in questioning and challenging the "long-held and socially reinforced characterizations" of writing that faculty hold in their fields (p. 229). We likewise work to build "active, dialogical reflection . . . [that] effectively mak[es] the familiar strange," a process Flash (2016) argues "can catalyze a dismantling of entrenched and unproductive pedagogical thinking" (p. 231). Notably, both the NC State and Minnesota programs exist in the context of a university mandate for the articulation and assessment of communication or writing-related curricular goals; our work takes place in the absence of such a driver. However, we share a recognition of the time and iteration sponsoring these conversations require, as well as the need for situated strategies to draw out disciplinary knowledge and surface assumptions.

STEM Programs Pursuing Curricular Change around Writing

While WEC programs provide crucial models for initiating curricular change, STEM curricula in which writing goals are integrated across all four years of an undergraduate program seem to be relatively scarce, likely due to barriers posed by institutional structures. Vertical integration requires sustained support from key faculty campus units, financial commitment, and community buy-in. However, one notable example is the materials science and engineering (MSE) department at Virginia Tech, which instituted a comprehensive writing and communication program led by a director from the English department. The program includes eight required courses taught by MSE faculty with team-teaching support from the director (Hendricks and Pappas,

1996). At the University of New Haven, engineering faculty were trained to develop course materials as part of the Project to Integrate Technical Communication Habits (PITCH), in which instruction on technical communication genres and habits was scaffolded across all four years in seven STEM majors (Harichandran et al., 2014). In examples like these of vertical integration of writing instruction in STEM, curricular change was typically guided by learning goals and supported by individuals with expertise in technical communication and/or WAC, illustrating the efficacy of collaborative goal development (Ford, 2012; Mathison, 2019; Patton, 2008).

Faculty views of writing are instrumental in building toward curricular change. When developing curricular goals for writing, both WEC and STEM literature demonstrate the importance of centering student writing and leveraging points of tension as "pivot points of change" rather than attempting to reduce these points to "resistance" (Flash, 2016, p. 230). As Michelle Cox, Jeffrey Galin, and Dan Melzer (2018) write, "there is a complex and codependent relationship between the structure of campus writing programs and faculty ideologies regarding writing" (p. 98). Regarding our own team, we have found that narratives of student writers, or "backstage" teacher-to-teacher talk (Goffman, 1956; Vaughan, 2007), play a key role in writing instruction. Because of genesis amnesia—the phenomenon whereby we forget how we acquired knowledge and skills (Bourdieu, 1977)—along with the tendency for memory to become increasingly conventionalized over time, these narratives of student writers can become typified and allegorical, obscuring the complexity of literacy development.

In the sections that follow, we investigate one of the central principles of the WEC approach: "unchallenged, tacit-level conceptions of writing and writing instruction inform the ways writing is taught and the degree to which writing is meaningfully incorporated into diverse undergraduate curricula" (Flash, 2016, p. 20). As Stacey Sheriff (2021) points out, WAC and writing-in-the-disciplines (WID) research has yet to fully explore "the dynamics of how groups of faculty come to articulate their tacit knowledge and disciplinary expectations for writing" (p. 147). Our contribution addresses these dynamics in the initial stages of curricular goal development across departments to better understand and respond to the "fits and starts" (Ware et al., 2022) of curricular change.

Our Context and Approach

Begun in 2016, the Writing Across Science and Engineering (WAES) program is a transdisciplinary WAC initiative centered in the Grainger College of Engineering at the University of Illinois Urbana-Champaign. At the time the focus groups were conducted, our team included six faculty members and six graduate students from engineering, the sciences, and writing studies. We follow a transdisciplinary action

research (TDAR) model (Stokols, 2006) in which assessment and research are interconnected in an iterative cycle. Our primary interventions include a semester-long faculty learning community (FLC) that meets weekly, followed by individualized mentoring of faculty by teams of writing studies and STEM mentors (Gallagher et al., 2020; Kovanen et al., 2022; Ware et al., 2019; Yoritomo et al., 2019).

Seeking to integrate the efforts of course- and department-level interventions and to promote a more distributed model of writing instruction, we began in the summer of 2018 to develop departmental learning goals for writing that could be used to guide curricular assessment and change. During a FLC for physics that fall, we facilitated conversations about the kinds of texts faculty expected students to produce in their careers and which learning objectives might be relevant for their curriculum. Those conversations informed what we came to call the Learning Goals and Shared Values for Writing in STEM (hereafter referred to as "Learning Goals"), which were discussed and revised across several WAES team meetings. We provide an excerpt of the Learning Goals in Table 1, which highlights the disciplinary values coded most frequently in our analysis of the focus-group discussions. The Learning Goals were designed as a tool for working with faculty to assess and implement writing across curricula and individual courses, not as a student resource or a one-size-fits-all set of writing objectives.

Table 1.
Example excerpt of the Learning Goals and Shared Values for Writing in STEM.

Disciplinary Value	Goals Surrounding Value
Precision	• Employ specific language • Learn and adhere to conventions • Describe methods so they can be repeated
Clarity	• Favor simple sentence structures • Recognize and follow audience's expected organization • Organize ideas so old information leads into new
Evidence	• Interpret results and explain their significance • Identify and evaluate relevant data • Design experiments and models

To further develop the Learning Goals, we decided to hold faculty focus groups. Although "focus groups," "faculty learning communities," and "WAC workshops" are descriptors sometimes used interchangeably to refer to groups of faculty learning together about writing pedagogy, in this paper, the term "focus groups" refers to the research method we used to elicit feedback on the Learning Goals. This approach

builds on prior WAC work in which focus groups were used as a step toward curricular revision (e.g., Peters, 2009). We identified three primary objectives for the focus groups: (1) surface tacit knowledge about writing pedagogy and development while exposing assumptions, (2) elicit feedback on the Learning Goals and ways to adapt them for different departments, and (3) foster conversations about vertically integrating writing across engineering curricula.

In our team meetings and interventions, we are privileged to observe the nonlinear, affective, and bumpy process through which faculty reevaluate their ideologies of writing and revise their writing instruction. Ryan M. Ware and Julie L. Zilles (2024) recently described this phenomena as "discursive turbulence" (p. 140). The framework of discursive turbulence reminds us that uncertainty and "affective struggle" are core components of instructional change, and it compels us to pay attention to the ways in which pedagogical change is intertwined with "professional identities and foundational conceptions of writing" (Ware et al., 2022, p. 4). In the faculty focus groups, we observed how this process surfaced tensions between faculty instructional contexts, responses to student writing, and visions for writing across the curriculum. Discursive turbulence was particularly evident in the persistence of generalized conceptions of writing and challenges in envisioning integration.

Methods

Description of Focus Groups

In Fall 2019, members of our team organized and facilitated focus groups in three departments: civil and environmental engineering (CEE), crop sciences, and physics. These departments were selected based on prior interventions and team connections. We hoped to hear from faculty who had participated in the physics FLC whether they felt the Learning Goals reflected their input; meanwhile, the CEE and crop sciences focus groups provided an opportunity to explore how well the Learning Goals represented a range of engineering and science disciplines. The CEE focus group was hosted by the department's curriculum committee. The composition of the focus groups, organized by faculty rank and history with WAES, is provided in Table 2.

Table 2.
Focus group composition.

	CEE	Crop Sciences	Physics
Rank			
Nontenure track	2	2	1
Asst. Prof.	0	0	2

	CEE	Crop Sciences	Physics
Assoc. Prof.	3	3	0
Prof. (Admin. Role)	1 (1)	2 (2)	4 (2)
History with WAES			
None	2	7	3
FLC participant	2	0	1
Mentee	1	0	1
FLC & Mentee	1	0	1
WAES team member	0	0	1

The majority of the focus-group members were tenured faculty, and five total held administrative roles such as department head or director of undergraduate studies. Crop sciences focus-group members had no prior history with WAES aside from being colleagues of Julie Zilles, our principal investigator. CEE and physics participants had about the same level of prior engagement with WAES, as faculty were present who had participated in both past FLCs and WAES mentoring. A WAES team member was also in attendance as a physics focus-group participant.

The focus groups were facilitated by a WAES graduate-student research assistant in writing studies, Megan Mericle, and the WAES principal investigator and crop sciences faculty member, Julie Zilles. The focus groups ranged from just under an hour (CEE) to around one hour and twenty minutes (physics and crop sciences) in length. To ground the conversation in what faculty valued in student writing as well as where they saw room for development, we began the focus groups with a discussion of student writing, using Patricia Carini's (2001) process of descriptive review. According to Rob Simon (2013), "the goal of the process [is] to remain descriptive rather than evaluative," "situating our readings in 'what is' rather than focusing attention on what isn't working" (p. 124). This process aligns with our own goal of unearthing tacit knowledge rather than centering established feedback practices. By approaching student writing at a slower pace, descriptive review allows faculty to attend to what they value about student texts. When possible, two contrasting writing samples were chosen—one written by a student early in their program, and the other from a student in an upper-division course (Appendix 1). Due to a lack of available student samples approved for use, the CEE samples came from two different assignments from the same advanced composition course. In accordance with the descriptive-review process, each sentence was read by a different faculty member, who then added an observation. Each sentence was read three times as turns proceeded around the table to ensure full participation. Faculty members were asked to be descriptive rather than

evaluative and were given prompting questions to guide their observations (Appendix 1). After reading and responding to both samples, faculty members were asked to identify the broader themes appearing in their observations. We then shared the Learning Goals and prompted the faculty members to identify connections and gaps based on their knowledge of writing in their discipline.

Data Analysis

The focus groups were video- and audio-recorded with participants' informed consent (IRB #18471). Julie Zilles took field notes along with another WAES team member, Patrick Coleman, who was a graduate-student research assistant in physics at the time. According to our IRB protocol, participants chose whether to be referred to using a pseudonym or their real name.[2] We transcribed the conversations utilizing a partial verbatim approach, including false starts and repetition as potential markers of interruption, changes in word choice, or uncertainty. However, as we are not engaging in detailed linguistic analysis, we removed back-channel talk (e.g., "um") in order to save space and focus on points of analysis (see Appendix 2).

Following transcription, we composed research memos for each focus group. Drawing on grounded theory methods (Strauss & Corbin, 2015), we identified initial resonances across focus groups in a secondary memo. We then segmented the faculty responses from the slow group reading by conversational turns (Geisler & Swarts, 2019), conducting open coding to get a more holistic view of trends in the observations. Following open coding, we analyzed the slow group reading responses again using the Learning Goals as a coding scheme. For the turn-based practice of slow group reading, the combination of open coding and coding according to an existing scheme allowed us to gain insight into both how faculty responses aligned with the writing values identified in the Learning Goals, and how faculty co-constructed narratives and values around student writing that were not entirely captured by the Learning Goals. The remainder of each focus group was analyzed through an iterative process informed by themes emerging from the memos and conversations with the WAES team.

Findings

Theme 1: Moving from Observation to Evaluation

Despite grounding the focus groups in Carini's (2001) descriptive-review process, which centers observation over evaluation, we found that the faculty responses to the student samples were largely evaluative. In the open-coding process, 61 percent of faculty turns were labeled as evaluations (48 percent negative and 13 percent positive), while only 39 percent of turns were labeled as observations—that is, defined as descriptors or questions posed in relation to the text absent of assessment

2. Faculty pseudonyms are labeled using an asterisk (*).

or evaluative language (i.e., "good," "bad," "ineffective") (Table 3). Faculty participants tended to focus on textual features, frequently sharing judgments in which they voiced preferences for alternative constructions.

Table 3.
Descriptive-review faculty turns coded by observation and evaluation.

Dept.	Code	Turns (#)	Turns (%)[α]	Example Faculty Responses
CEE	Observation	6	17	I am not quite sure what they mean by notched, and I don't know what PMMA is.
	Negative Evaluation	18	51	Verb tense here is incorrect. It's either plural "tests" or "bending test was performed."
	Positive Evaluation	11	31	I already like this author better. . . . I find this to be an informative sentence.
Physics	Observation	48	45	So what I notice is that this sentence is written in the passive voice.
	Negative Evaluation	51	48	Long sentence. . . . Oh, too too many problems with this sentence.
	Positive Evaluation	8	7	Especially after reading the last excerpt, it just stands out how much more succinct this one is.
Crop Sciences	Observation	23	42	So my observation there is it's relatively informal with the "sorry home owners."
	Negative Evaluation	25	45	Yeah, it's . . . forty-some words. . . . Just feels like a forever sentence. . . . I don't think it's a very effective sentence.
	Positive Evaluation	7	13	[I]t's pretty clear in terms of giving some specific data, which is I think- which is good.
Total	**Turns**	**197**		
	Observation	77	39	
	Negative Evaluation	94	48	
	Positive Evaluation	26	13	

[α]Percentage of turns classified into this code in either the specified department or the complete dataset (total).

The evaluations of students' writing were frequently hedged. Faculty framed evaluations as their own preferences and perspectives, using phrases like "in my opinion," "I don't like that," and "it bothers me" (Conrad, 2017; Hyland, 1998). Hedges were used to mitigate uncertainty around error and as invitations to other faculty to collaboratively investigate issues of clarity. The persistence of hedging in faculty's writing evaluations likely derives from their enculturation in disciplines where hedging is expected in cases where the data provide insufficient proof, along with the social dynamics of the focus groups and potentially a lack of confidence in evaluating writing. Reevaluating characterizations of faculty "resistance" to WAC interventions, Judith Halasz and Maria Brincker (2006) found that faculty sometimes avoid WAC approaches due to a lack of confidence in teaching and responding to writing, leading them to treat writing instruction as the responsibility of English departments. While hedging was possibly a result of the focus-group faculty's unfamiliarity with WAC, the hedged evaluations also created space to co-construct values around textual features in student writing.

In the CEE focus group, these hedged evaluations frequently centered on passive voice. One faculty member, Ashlynn Stillwell, initiated the conversation. Hedging her evaluation as a preference, she noted a sentence was "passive voice, and knowing that this is a lab report *I would prefer* to see it phrased as taking ownership over one's performance of this bending test" (emphasis added). Kelly Mixon* added that passive voice made it more difficult to determine what the student had done in the lab. In response to a different sentence, Ashlynn connected passive voice directly to a question about students' roles in conducting class laboratory tests: "because of the use [of] passive voice, I'm not clear whether the students did this test, or it was done for them." Remaining observations of passive voice were bundled with other remarks about textual features; since the problematic nature of passive voice was already established, faculty spent less time hedging and rationalizing their evaluations.

Negative evaluations of passive voice were backed by several different rationales. At certain times, passive voice was said to obscure clarity in methodological descriptions; at others, it prevented students from taking responsibility for their actions; and in yet other cases, it allowed students to take credit for aspects of the experiment that were completed for them. Faculty's expectations regarding passive voice were grounded in classroom contexts and did not necessarily accord with professional engineering conventions, which, as Ashlynn noted toward the end of the focus group, are still contested:

> [W]e as an industry . . . have lagged behind in innovation sometimes, such that our primary professional organization, American Society of Civil Engineers, in their journals still do not allow first-person active voice. . . . I think we could move forward as a discipline with more conventions around

> writing like that. . . . [E]ntire generations of civil engineers . . . stressed that you never use "I," "we," "my," "us" in technical writing, which I think is perhaps several decades ago, of a convention.

As evidenced by Ashlynn's comment about changes in engineering conventions, different disciplinary values, classroom contexts, and professional standards are all implicated in faculty members' evaluations of passive voice. In a corpus linguistic study of civil engineering writing, Susan Conrad (2018) describes the wide range of rationales in engineering communication guides for and against passive voice. Her own study revealed complex uses of passive voice in nonacademic civil engineering writing to place old information before new concepts and relay information more concisely. The conversation around passive voice in the CEE focus group illustrates how systems of values and tacit knowledge impact the consensus on writing features. Across the focus groups, the conversations around and evaluations of student writing reveal deeply held beliefs concerning sentence-level choices that, we argue, should be surfaced and interrogated.

Theme 2: Constructing Student Writers' Scientific Becoming and Processes

In keeping with critiques of current-traditional rhetoric (Crowley, 1998), and in part due to the nature of responding to decontextualized student work, the focus groups largely analyzed the texts as products rather than the students' processes in creating them. As products, the writing samples were seen as a direct lens into students' scientific thinking. This approach was prompted, at least in part, by one of the guiding questions of the descriptive-review process: "What does this sentence communicate about the author?"

For example, in the CEE focus group, Sotiria Koloutsou-Vakakis made the following comment on a writing sample: "[T]he last two sentences actually changed [the] opinion I had from the first sentences that the writer is somebody who has very clear thinking . . . now it gets cloudy." Similarly, during a discussion in the physics focus group about how an equation was integrated into a sentence, Brian DeMarco claimed that the student's use of the equation "shows the way they're thinking about physics at this point, right? They just need an equation to plug numbers into, that's the thing that's important." The faculty frequently used the writing samples to identify room for growth in students' scientific practices and thinking.

In the physics focus group, a conversation around word choice evoked reflections reminiscent of David Bartholomae's (1986) "Inventing the University." Mats Selen argued that one student was "trying to make it sound kind of fancy . . . big words and, and, you know, I think . . . they're writing in a way that they think sounds, like, professional." While Mats observed limitations in students' understanding of

effective scientific communication, in the crop sciences focus group, Reid Christianson felt that a lack of clarity around methods demonstrated that "the student lacks the format of how to set up an experiment. And so they're showing that they're not trained yet in terms of how to put the pieces together."

In their conversations, faculty constructed writers who lacked training, were confused about methods, and were unfamiliar with the expectations around scientific communication. These responses evoke genesis amnesia (Bourdieu, 1977) by conflating writing ability with scientific knowledge and privileging conventionalized accounts that flatten the diversity of student writing experiences. Faculty sometimes tied their evaluations to speculations about students' processes, especially in terms of time management. For example, David Ceperley, a physics professor, remarked that a student defining terms in a conclusion was "trying to pad the report, because presumably, this has all been defined several times before." David's comment imagines a student composing a last-minute report, trying to find the fastest way to meet length expectations. However, Keya Vig* recontextualized this construction as indicative of physicists in the field rather than amateur error: "I do that sometimes. In writing grant proposals."

Time management came up in the crop sciences focus group as well, suggesting it is both a common concern and a possible entry point for shifting faculty's perceptions. This topic marked a key moment in the CEE focus group and our team's subsequent discussions, as it encouraged a shift from a deficit-based, product-oriented view of a student's ability as a writer to a process-oriented perspective allowing for pedagogical change. Following a series of critiques, Omar Faris* observed,

> I have seen students . . . get to the body of the narrative of the report and they . . . delay the abstract part, and that's typically the last task . . . and it is typically rushed, so they grab sentences from the report. . . . [T]o me, it doesn't necessarily reflect . . . whether he has a mastery of the words, but more in terms of time management. . . . [T]his problem with language may be reflected in the other parts of the course.

Omar's comment encouraged the other faculty members to consider the writing process, as evidenced by Sotiria Koloutsou-Vakakis's next observation: "I would agree with [Omar], this sentence shows somebody who was either very rushed, or is very confused about what they actually observed and what they did in the lab." Sotiria moved from interpreting writing as a direct reflection of students' thinking to considering the contexts in which students compose texts.

Theme 3: Discrepancy between Descriptive-Review Evaluations and Learning Goals Assessment

Although our aim was to use the descriptive review of student writing to ground the discussion of the Learning Goals, we observed a discrepancy between these two parts of the focus groups. While the descriptive-review process elicited an animated discussion around textual features, student becoming, and audience expectations, faculty largely accepted the Learning Goals. They expressed a few discipline-specific concerns and identified potential missing elements before moving to a discussion of how they might apply the Learning Goals in their department, as summarized in Table 4.

Table 4.
Summary of departmental responses to the Learning Goals.

	CEE	Crop Sciences	Physics
Accepted?	Yes: "you could find and replace physicists with engineers"	Yes: "you could find and replace physicists [with] crop scientists"	Implicit yes: discussion focused on what was missing
Discipline-Specific Concerns	CEE-specific audiences (clients, lawyers), field conventions	None raised	Differences between theorists & experimentalists
Missing Elements	More emphasis on audience	Storytelling, professionalism	Storytelling, more emphasis on interpretation
Comments on Application	Interest in resources to give directly to students, concerns about motivating students to care about writing	Time as a major barrier	Concerns around being too general for integration, course content and time constraints, lack of TA training in giving writing feedback

In all three groups, there appeared to be widespread acceptance of the content of the Learning Goals. Although the Learning Goals had been originally developed based on physics faculty input and were framed as physics writing goals and values, both CEE and crop sciences faculty stated that we could "find and replace physicists" with members of their respective fields and the Learning Goals would still be accurate. In physics, the acceptance of the Learning Goals was more implicit, perhaps because they were already framed in terms of the field's disciplinary values. Discussion moved quickly in the physics focus group to what faculty felt was missing, and no points were raised about revisions to existing content.

The faculty involved in the focus groups raised a few discipline-specific concerns when asked about ways to ensure that the Learning Goals represented their field. In CEE, faculty felt that the Learning Goals focused primarily on academic audiences, while in their field and its associated career paths, writers navigated a wide range of audiences beyond academia, including city council members, clients, and lawyers. To better reflect the writing values of CEE, faculty expressed that the Learning Goals could better emphasize a wider range of engineering audiences and genres. In crop sciences, however, no discipline-specific concerns were raised. Faculty instead agreed that the Learning Goals applied to "general science." When asked about the applicability of the Learning Goals to nonacademic careers in crop sciences, Reid Christianson responded, "[W]riting is kind of universal, and a good writer is going to be a good writer in every setting."

In contrast, faculty in the physics focus group considered the potential universality of the Learning Goals to be problematic. Yonatan Kahn asked, "Is it possible that writing in physics is actually qualitatively different than writing in other branches of science?", adding that he saw the Learning Goals as limited in utility because he could replace "physicists" with "biologists" and the values would still hold. Yonatan argued, "[A] set of principles for writing in physics should acknowledge that distinction [between the way theorists and experimentalists tell stories] and figure out how to work within it." However, the physics focus group did not identify any specific principles or conventions associated with experimental or theoretical physics writing, aside from using the document-preparation software LaTeX. Outside of the select disciplinary concerns raised, faculty relied on generic accounts of writing in the Learning Goals discussion.

Faculty suggested a few possible additions or changes to the Learning Goals, aside from the suggestion from CEE to emphasize writing for different kinds of audiences. For example, the importance of storytelling emerged in both the crop sciences and physics focus groups. One of the physics faculty members commented that effective storytelling is "how you get proposals funded." Since faculty expressed broad agreement on this feature, we incorporated it in later versions of the Learning Goals. In the physics focus group, Brian DeMarco also called for more emphasis on interpretation. He observed that the Learning Goals included "interpret[ing] results," but the importance of "the meaning of what you've done" and tying it to the "storytelling aspect" of scientific writing was not captured by the Learning Goals.

In all three focus groups, faculty moved of their own accord to discussing possible applications of the Learning Goals; however, many expressed feeling overwhelmed. In CEE, one faculty member noted, "[I]f you gave that to the student, they would just throw it away." While not our intended purpose, this perception of the Learning Goals as a resource to be shared directly with students appeared in all three groups.

This faculty response likely indicates familiarity with scalable, transposable writing resources that can be added to curricula without pedagogical restructuring, along with a lack of curricular space or faculty bandwidth to envision applications of the Learning Goals beyond direct transmission to students. Faced with these obstacles, faculty discussed solutions in the form of outside writing-instruction support, such as writing software (i.e., Grammarly), the campus writing center, the required first-year writing course, and high-school writing preparation.

It was in the physics focus group that the most debate around vertical integration and the placement of writing in curricula arose, centering on the motivation for and purpose of the Learning Goals rather than on specific content. When Lance Cooper, a member of the WAES team, noted that the focus group was a starting point for conversations about integrating writing across the physics curriculum, Keya Vig* responded, "Are we going to talk about why you'd want to do this at all?" Keya raised concerns about adding writing to her upper-division physics course, where students were "struggling already . . . it's like learning a completely new language." While other faculty suggested ways to integrate writing into her course without sacrificing content, Keya expressed reservations:

> The problem is it takes a lot of time and energy to actually write something well. I'm just saying . . . when I write a paper, we edit over and over and over again. . . . I guess we can expect- request- require certain things from the lab report. But I'm wondering if we should require a lot.

Keya raised concerns about "dilution," questioning whether "heap[ing] too much onto a course" would devalue both existing course content and writing instruction. For Keya, vertical integration reflected a "piecemeal" approach, and she doubted whether those pieces would add up to a substantive understanding of writing in physics.

Keya's concerns influenced her response to the Learning Goals: "So I (.) don't (.) see the value of this [short laugh] . . . whole thing. The way it's written right now. Because I feel like it's too general and too specific at the same time." Keya's concerns were closely tied to her own writing-instruction experience. She remarked that she was a "horrible" writer as an undergraduate student, and she grappled with the question, "What would have helped me?" Recognizing that she never had the importance of writing stressed for her as an undergraduate (she did not receive writing feedback until graduate school), Keya was still thinking through ways to address this gap as the focus group drew to a close. The diverse personal writing and teaching histories of focus-group participants shaped how they envisioned curricular goals, even as participants largely agreed that vertical integration was both challenging and necessary.

Altogether, the responses to the Learning Goals suggest that the focus groups did not provide sufficient time or space to build explicit awareness of tacit disciplinary conventions and differences. Faculty articulated very few discipline-specific changes to adapt the Learning Goals to their departments. While the CEE curriculum committee requested that WAES share the Learning Goals, and faculty members have drawn on them in individual, WAES-impacted course redesigns (Renna et al., 2022), vertical integration into curricula remains elusive. The focus groups provided a space for faculty to reflect on writing and writing pedagogy, but they expressed confusion and uncertainty about how the Learning Goals might inform coordinated curricular change.

Discussion

The focus groups provided us with important information about barriers and entry points to curricular change. With regard to the former, they illustrated the complex entanglement of classroom histories, tacit knowledge about writing, and institutional constraints affecting writing instruction. Faculty across focus groups expressed the belief that writing is a universal skill, rather than a set of practices that require understanding of different disciplinary values and expectations. Although faculty provided rich responses to student writing during the descriptive review, surfacing the tacit knowledge underlying those responses and engaging with the more abstract Learning Goals proved more challenging. Furthermore, a focus on current instructional demands foreclosed other ways of imagining writing instruction. For instance, Keya's constraints in teaching a challenging course with many content demands made it difficult to envision incorporating writing instruction in the physics curriculum as a whole without resorting to an ineffective, "piecemeal" approach. We find these barriers indicative of the discursive turbulence (Ware & Zilles, 2024) that emerges from pedagogical change. The framework of discursive turbulence reminds us to attend closely to the contradictions in faculty assessments of student writing; it also encourages us to see the disconnect between the two parts of the focus group as indicative of the long-term, turbulent nature of WAC work.

Entry points to building disciplinary goals and investment in vertical integration were also identified through the focus groups. While the responses to student writing were largely evaluative, the variety of rationales expressed by faculty helped to illustrate how values, histories of writing instruction, and beliefs surrounding scientific writing informed faculty evaluations. Following a WEC approach (Flash, 2016; Hughes, 2020), we name the conceptions of writing that emerged—such as the belief in writing as a universal skill and issues of passive voice and clarity—in order to better account for them in ongoing conversations with disciplinary faculty. The persistence of hedging also invites opportunities to make space for multiple flexible

disciplinary writing goals and to build faculty confidence around giving writing feedback. Another entry point is how the descriptive-review method disrupted product-centered views and prompted faculty to co-construct process narratives. When asked to imagine what each sentence communicated about the author, faculty envisioned possible hurdles in the writing process and articulated shared experiences about working with student writers. These points of resonance could be stepping stones to collaborative initiation of pedagogical and curricular change. By imagining students' writing processes and leveraging moments of disagreement and hedging, WAC stakeholders can help faculty build more complex, concrete, and explicit disciplinary expectations, which can then be communicated more transparently to students via course instruction and curricular goals.

Although the focus groups provided important information, progress towards our initial aims was limited. While the descriptive-review process helped us begin to surface tacit faculty assumptions and expectations around writing, the single, fifty-to-eighty-minute sessions were too short to progress from tacit, individual faculty observations to explicit, shared disciplinary knowledge. This limitation is consistent with research demonstrating the long and turbulent process of conceptual change (Ware & Zilles, 2024). More importantly for our purposes, the bridge we envisioned connecting the descriptive review and the discussion of the Learning Goals was not realized. Perhaps another strategy for transitioning between the two parts of the focus group would have been more effective, or perhaps the disconnect reflects an inevitable difficulty in moving from something so concrete and familiar to something more abstract and unfamiliar. In all three focus groups, there was confusion around the purpose of the Learning Goals, along with questions and comments about their implementation, which limited the feedback on the goals themselves. Our third objective of working towards vertical (curricular) integration is a long-term one, not directly addressed in our plan (Appendix 1), but there was considerable conversation in the physics group around the purpose and feasibility of vertical integration. This conversation may have emerged in part because of generative tensions between WAES team members, faculty who had been involved in previous WAES interventions, and faculty unfamiliar with WAES. To our knowledge, all three of the departments involved in the focus groups continue to have faculty interested in vertical integration, but to date changes have largely been limited to individual courses.

One general limitation of our approach is that the group structure of the focus groups, combined with the high impact of curricular change on faculty labor, may lead members to focus on agreement rather than express divergent viewpoints. As Sim (1998) observes, this is a limitation of focus groups in general, and it can therefore be inaccurate to use focus groups as a measure of consensus. Furthermore, the

focus groups represented only a portion of departmental faculty, of whom tenured faculty were an overrepresented population.

Future Work and Implications

To continue working toward the objectives we articulated in this paper, particularly those of surfacing tacit knowledge about writing pedagogy and fostering conversations about vertically integrating writing across engineering curricula, we are currently experimenting with more targeted conversations with faculty and with using the Learning Goals as a curricular assessment tool. One example of a more targeted conversation occurred at a recent crop sciences faculty meeting. We asked faculty to reflect on and discuss whether each value might be relevant to writing in crop sciences and whether it was (or was not) reflected in their courses. By involving a wider segment of departmental faculty, this strategy provided greater context about where writing values are showing up in crop sciences curricula, thereby helping us identify possible course connections and interventions. On the curricular assessment side, we have used the Learning Goals as a coding framework, assessing course materials to ascertain the placement of writing concepts and instruction across a single curriculum (Carzon et al., 2024). Our intent is to use these data about which elements of the Learning Goals are addressed by, or absent from, a curriculum as a basis for a more specific conversation with faculty. We hope to learn how the current state of the curriculum does and does not reflect their disciplinary values, using any disconnects between the two as a starting point for faculty to envision future changes. Following WEC approaches (e.g., Anson & Dannels, 2009), we aim to build awareness of existing writing instruction practices that could be made more explicit while providing a more concrete assessment of gaps in vertical integration.

For WAC/WEC stakeholders as a whole, our close analysis contributes to a better understanding of the powerful systems of disciplinary expectations among faculty, offering a starting point for pushing faculty to articulate tacit knowledge (Sheriff, 2021). Noting Jamila Kareem's (2020) call to center student goals, but also being sensitive to the ways in which the purposes and constraints of writing in the sciences and engineering influence faculty in these disciplines, we highlight two complementary needs: delving more into students' goals and diverse literacies, and better understanding the writing practices and values of STEM workplaces through studies such as Susan Conrad's (2017) linguistic analysis of civil engineering documents and Marie Paretti and Julie Ford's (2022) analysis of engineering workplace genres.

The focus groups demonstrated the difficulty of surfacing and articulating discipline-specific writing expectations and of translating those expectations into concrete pedagogical changes. The challenges we identified in the focus groups, along with their resonances in WAC/WEC literature, point to a need for an expanded

tool kit of strategies—beyond the workshop and the writing-intensive course—that can be adapted to local contexts in order to surface disciplinary faculty's tacit writing knowledge and to collaboratively construct and implement disciplinary learning goals. While we do not know exactly what strategies are most likely to succeed in other institutional contexts, the focus groups, along with our work as a whole, emphasize the importance of long-term transdisciplinary relationships. Based on our experience, other key measures may include the assessment of student writing and departmental curricula (as is central in the WEC approach; e.g., Anson & Dannels, 2009; Flash, 2016), integrated, iterative research and intervention (such as a transdisciplinary action research model; see Stokols, 2006), and action-oriented approaches that give disciplinary faculty a clear entry point.

Despite—and in some ways because of—their limitations, the focus groups helped us recognize barriers to building longer-term investment in pedagogical and curricular change. Our findings illustrate how these changes lead to discursive turbulence, or the iterative and nonlinear adoption of writing conceptions and pedagogies (Ware & Zilles, 2024). The focus groups, along with our WAES FLCs and mentoring partnerships, have made it clear to us that STEM faculty recognize the importance of writing, but many lack the time, space, and tools to implement explicit writing pedagogies.

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Appendix 1: Departmental Focus-Group Handouts with Student Samples

The following handout was given to department faculty at the beginning of each focus group.

The process of slow reading student work was developed by Patricia Carini in the K-12 educational setting, but it has since been used by researchers at the university level for faculty development and instructor training. We will use this method to spark conversations about ways to take into account what students know and what they need to know when setting objectives for writing across the curriculum.

The goal is primarily to take the opportunity to approach student writing at a slower pace (as we are often pressed by deadlines and busy schedules) and attend to what we value about student texts. It is a process of noticing and observing. According to Simon (2013), who carried out slow group reading in his work with student teachers, "the goal of the process [is] to remain descriptive rather than evaluative: situating our readings in 'what is' rather than focusing attention on what isn't working" (p. 124).

Slow Group Reading Process

1. Each sentence will be read three times by three different people. After you read the sentence, if you could, offer a brief observation about what you notice. Keep the following questions in mind to guide your observations:
    i What is this sentence doing for the text?
    ii. What does this sentence communicate about the author?
    iii. What do you notice about the tone or style of the sentence?
    iv. What features (word choice, punctuation, syntax, etc.) in this sentence stand out to you?

Physics Samples

Sample 1 (excerpted conclusion from a first-year physics lab report):
The study conducted measured the speed of sound using an IOLab light and microphone sensors. In the experiment, a beam of light shined onto the IOLab was subsequently interrupted when a block of falling wood obstructed the light intensity and produced a soundwave registered to the IOLab. Using the equation: $V = D/\Delta t$, the distance between the block and the IOLab over the time difference between the interrupted light intensity and generation of a sound wave was used to calculate the speed of sound. . . . Over the course of the experiment, in order to minimize uncertainty, several measures were taken during the collection of the data. First, during the experimental setup, a flashlight was used instead of a laser pointer because the beam of light

needed to hit the light sensor of the IOLab consistently. The flashlight was also taped down onto a desk to insure that the distance between it and the IOLab did not vary. Moreover, the distance between the IOLab and the flashlight was taken using two meter sticks. Noticing that the two meter sticks may have shifted, we decided that the uncertainty for the measurement should be approximately +/- 0.02 m.

Sample 2 (full abstract from an upper-division physics lab report):

In this lab we measured the response of ferromagnetic materials to external magnetic fields. We were particularly interested in the mechanics of the phase transition between paramagnetic and ferromagnetic states. We used this data to produce B-H curves for toroidal materials within an inductor, from which we were able to observe the nature of the phase transition in terms of microscopic magnetic domains within each material. We then investigated how temperature affects this phase transition by comparing B-H curves taken at various temperatures, as well as measuring the magnetic susceptibility in response to a wide range of temperatures. We found that there is a critical temperature at which the dependence of magnetic susceptibility on temperature is nearly linear and decreases at a much quicker pace than below this critical temperature.

Civil and Environmental Engineering Samples

Sample 1 (abstract from an upper-division CEE lab report):

Bending tests were performed on notched specimens of 1045 hot rolled steel, 6061 aluminium, and PMMA. The notch types included sharp notch, also known as sharp cracks for all three materials, and rounded notches for just the metals. Bending test were performed using an Instron Model 4400 load frame. Photoelasticity tests were performed on PSM-1. Their visual stress distribution was discussed to learn the importance of photoelastic materials and tests. The metal specimens were both strengthened by the inclusion of a notch, the round notch being better for strengthening. The brittle PMMA specimen was weakened by the inclusion of a notch. A notch on the surface of tension will be weaker than a notch on the surface for compression. Finally, photoelastic properties are useful for the planning and design of elastic materials.

Sample 2 (conclusion from an upper-division CEE lab report):

The photoelasticity is useful for comparing stress concentrations between a specimen with a notch and a specimen without a notch. The photoelastic images can clearly show the differences between these two specimens. However, the photoelasticity cannot show the specific bending stress directly, which means it is not able to quantitatively compare the bending stress that specimens are subjected to. The results are only

applicable to elastic materials rather than elastic-plastic materials. It is because elastic-plastic materials will yield in bending, which will change the stress concentration and the stress distribution at the notch.

Crop Sciences Samples

Sample 1 (hypothesis response assignment from a first-year crop sciences course):

Situation: You are house-sitting and realize that all of the indoor plants are wilting and fading in color.

Hypothesis: The plants in the house are wilting and fading in color because their pots don't have enough water.

Experiment: To test my hypothesis, I would separate the plants into two groups. I would leave one group without water (sorry homeowners) and water the other plants until their soil was damp every week. I would be sure to include plants from all sides of the house in each group to keep the confounding variable of sunlight at a minimum. Every day I would make observations on the two groups of plants; I would record their color as well as how wilted their leaves are. At the end of the experiment, I would compare the data collected from the two groups and decide if the water reduced the plants' wilting and fading in color. If this was the case, I would support my hypothesis.

Sample 2 (excerpt from a graduate student's fellowship proposal):

Motivation: While nitrogen-rich fertilizers have helped sustain the increasing human population, they are also damaging the environment[1]. Managing the nitrogen cycle is one of the 14 grand challenges for engineering today[2]. Seventy-five percent of the reactive nitrogen that is produced by humans is applied to crops, making this one of the greatest anthropogenic impacts on the nitrogen cycle[1]. Much of the nitrogen applied to crops is leached to water, lost to the atmosphere, or lost as food and human waste, leading to numerous negative environmental impacts including global warming, smog, acid rain, eutrophication, loss of biodiversity, and soil acidification[1,3]. Thus, it is imperative that we help manage the loss of nitrogen from these systems so that we can sustain the benefits of fertilizer use while reducing the negative consequences. The proposed research will investigate the differences in gaseous nitrogen emissions to the atmosphere from different farm management practices and study the influence of such practices in the dynamics of soil microbial populations. My ultimate goal is to use this information as input to coupled biogeochemical-farmer agent models to provide policy makers and farmers with information about realistic, affordable nutrient management strategies that will allow them to maintain current crop yields and reduce negative environmental impacts.

References: [1] Galloway et al. 2003. *Bioscience*, *53*(4) [2] NAE. 2015. Grand Challenges for Engineering [3] Galloway et al. 2008. *Science*, 320

Group Discussion

2. After we've read two student examples this way, we'll open up to a conversation about patterns in observations that the group noticed.
    i. What kinds of features did you and your colleagues tend to notice?
    ii. What resonances or disconnects did you observe between the observations, particularly as each stood on its own without contestation or development from others?
    iii. Based on these examples, what would you say that you value about student writing, and what would you say that students struggle with when writing in your field?

Response to Learning Goals and Shared Values

3. To end today, we'll take a look at our current objective framework. Potential applications for this framework on a curricular level include using it to see what writing goals courses are already addressing, and where there might be gaps. On the level of faculty mentoring and course design, it can be used as a springboard to articulate what instructors want their students to work toward in specific courses.
    i. What overlaps do you see between the goals articulated in our conversation today and the objectives outlined here?
    ii. What potential disconnects or contradictions do you observe between our conversation and this objective framework?
    iii. *For physics:* Based on the way that you filled in this framework and your background in writing in physics, what would you say is consistent, and what needs to be changed? What points don't apply altogether that you would recommend cutting?
    iv. *For CEE and crop sciences:* When adapting these objectives to fit writing in [CEE/crop sciences], what would you say is consistent, and what needs to be changed? What points don't apply altogether that you would recommend cutting?

Appendix 2: Conventions for Transcription

We use the following symbols in the focus-group transcriptions:

[sigh]	brackets contain explanatory text or contextual additions
-	hyphens indicate an abrupt self-interruption
(.)	periods within parentheses indicate a pause
(..)	double periods within parentheses indicate a longer pause
. . .	ellipses indicate material removed from the transcript for concision
"Yes"	text within quotation marks indicates constructed dialogue
Italics	indicates emphasis placed on a word or phrase
!	exclamation marks are used to indicate rising intonation/excitement

We use conventional punctuation marks at the ends of sentences as well as periods to indicate slight pauses between phrases. We include repetitions of words but eliminate fillers such as "uh-huh," "mhm," and "uh."

Grammatical errors have not been corrected, and we have avoided the use of [*sic*] to avoid privileging some standardization/linguistic expectations over others.