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Don't Forget the End User: Writing and Tutoring in Computer Science

Abstract

By addressing how writing centers can work to help computer science students be ready for professional challenges related to writing in computer science fields, this study of computer science professionals and students illustrates how findings were applied to train a team of writing tutors. Drawing upon self-reports about writing in computer science jobs and writing in computer science classes, the authors identify both professionals' workplace writing challenges and students' perceptions of these challenges. Implications for writing center practitioners and researchers are discussed, including how writing centers can collaborate with computer science faculty to acquire resources, access the discourse of computer science assignments, and implement a similar training program in their centers.

Introduction

A central question facing university writing centers and the institutions in which they find themselves is how to help students prepare for the challenges of professional writing. Our study in two ways addresses this question as it pertains to the field of computer science:[1] first, by presenting the findings from our research study of computer scientists; second, by modeling how our writing center collaborated with disciplinary faculty to train a team of writing tutors. Since student enrollments in computer science departments have more than doubled in recent years (National Academies, 2018, p. 41), writing centers should expect to see similar growth in computer science enrollment at their universities; we hope this research provides insights and directions for how best to work with these students.

The research reported here began as a grant-funded project to enhance cybersecurity education in western Pennsylvania.[2] The importance of the grant project is underscored by a report showing that three skills, critical thinking, writing, and active listening, were rated relatively high in importance for computer science occupations—higher, in fact, than such skills as mathematics, systems analysis, systems evaluation, and management of resources (U.S. Department of Labor, 2017). The grant project focused on research and outreach to enhance the technical and communication skills of computer science students in our region. In this manuscript, we report on the project's communication component, beginning with gathering and analyzing interview data from working professionals such as software engineers, information technology (IT) analysts, network administrators, and technicians about writing done on the job (see Table 1). In the discussion that follows, we review literature on discipline-specific tutoring and writing in computer science to demonstrate the need for additional research that addresses discipline-specific tutoring to prepare students for writing in computer science careers. Then, we present our research on computer science professionals, who served to inform our training program for preparing tutors to offer discipline-specific writing tutoring to computer science majors.

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1 In this article, we use *computer science* when referring to the discipline, undergraduate major, or students who were the focus of the grant project. The project focused on cybersecurity training for students interested in or already studying computer science. We recognize cybersecurity does not describe the work all computer scientists engage in. For further discussion of these terms, see De Groot (2019).

2 The research reported in this article was supported by a grant (No. H98230-17-1-0325) from the National Security Agency of the U.S. Department of Defense; by the Indiana University of Pennsylvania (IUP) School of Graduate Studies and Research; and by IUP's Kathleen Jones White Writing Center.

The purpose of our study was to better understand the writing of computer science professionals so we could prepare tutors to help students be ready for the writing students will encounter as computer scientists. While there is no doubt much to be learned from holistic studies of the writing lives of computer science professionals, our goal was to investigate computer science professionals' writing, so we could train our tutors. We do suggest, though, in our conclusion, that further research might inquire into the texts computer scientists write, why they are writing them, who is reading them, and perhaps most important for writing centers, how to address prevailing notions of *error* in the field of computer science.

Literature Review

Our study engages with conversations, advanced recently by Lori Salem (2016), at the heart of writing center work: Who do writing centers serve, and how can writing centers achieve the mission to serve all students? Specifically, how can writing centers adapt their pedagogies to the ever-changing needs of students in communication-intensive technical fields? Our exploration began by looking to the future—What writing challenges will computer science students face on the job once they graduate?—and then to the present—How can writing centers help prepare students for these challenges while they are still in school? To answer these questions, we looked to professional computer scientists to understand the challenges students may face in the workplace.

Studying writers in the workplace has a rich tradition in composition. Research on the discourse communities students enter upon graduation can help educators align curricula with students' futures. For example, in *Writing in the Real World: Making the Transition from School to Work*, Anne Beaufort (1999) argues for greater attention to literacy skills and to workplace practices that inform teaching. More recently, Liberty Kohn's (2015) review of literature on university-workplace partnerships suggests students need additional writing support to meet the demands of most workplaces (see Beaufort, 2007; Dias, Freedman, Medway, & Pare, 1999; Freedman & Adam, 1996; Kain & Wardle, 2005; Russell, 1997). While these studies provide a precedent for studying workplace writers, it is important to note this research exists outside writing center contexts. Our study is innovative because we researched the workplace with the goal of using our findings to shape tutoring practices for students writing in computer science.

Over the past two decades, writing centers have tried to address the needs of students' writing in their disciplines in various ways. For example, Arlene Archer's (2007) and Amanda Greenwell's (2017) articles both discuss using discipline-specific model texts to prepare tutors to assist students with disciplinary writing. Similarly, Julie Moore, Erin SanGregory, Sarah Matney, &

Julie Morris (2010) suggest quick reference guides for discipline-specific tutoring. As Susan Dinitz & Jean Kiedaisch (2007) write, when tutors from different majors create handouts for their fields, knowledge of that field is "constructed by people *within* [emphasis added] the disciplines that form academic communities" (p. 6). Cory Hixson, Walter Lee, Deirdre Hunter, Marie Paretti, Holly Matusovich, & Rachel McCord (2016) suggest that writing centers collaborate with colleagues in other campus spaces to improve access for students unfamiliar with the writing center. From reading model texts, to drawing on tutor knowledge, to designing tutoring materials, to collaborating across disciplines, scholarship points to ways of using and creating discipline-specific resources. Other writing center researchers like Jennifer Craig (2016) have argued that generalist writing tutors, positioned outside a student's discipline, can relate to the experience of entering a new discourse community. Craig reminds us that students in technical communities are still new to their disciplines, and tutors outside these disciplines have perspectival advantages insiders do not (see also Remington, 2010; Savini, 2011; Weissbach & Pflueger, 2018).

What all these suggestions have in common is the recommendation that writing centers engage with other disciplines students write for. To that end, following a rhetorical approach to discipline-specific tutoring, we searched the U.S. Department of Homeland Security Digital Library (*Homeland Security*, n.d.) for model texts and writing resources specific to computer science we could use to prepare our writing tutors. We found only a handful of suitable materials. For example, a search of key terms (*writing skills*, *written communication*, etc.) yielded only a few documents about writing clear and cogent reports for safety and security concerns, such as intelligence analysis (Heuer, 1999); fire and paramedic response capabilities (Ugaste, 2009); and levels of risk faced by the public (Petersen, 2002). Another document intended to promote community preparedness and published one year after the 9/11 attacks instructs security officials on the importance of hearing and telling stories of disaster resistance (FEMA, 2001). A more recent document focuses on barriers to reaching linguistically diverse communities on health issues involving water, epidemics, and physical health (World Health, n.d.). These resources provide general advice about communicating clearly.

We were intrigued by reports about data-security breaches caused in part by failures to communicate dangerous conditions to nontechnical audiences. For example, an industry publication pointed to reports about warnings that are overly technical in nature and fail to translate threats into easy-to-understand language for upper management (Oberman, 2014), a problem echoed by our interviewees. Another report describes a severe cultural gap at the heart of misunderstanding certain technical communication. Writing for a U.S. Army newsletter, Sydney Freedberg (2015) describes the problems that arise when infantry soldiers try to communicate with cyberoperations units, whose com-

muniques they derisively referred to as "dolphin speak." The officer in charge of the cyberunit admitted, "We needed to learn to speak Infantry." Freedberg concludes, "The cultural challenge is arguably as large as any technological shortfall. In some cases, culture gaps even cause technological gaps because people don't invest resources in what they don't understand." These materials would prove helpful as we prepared the tutors, but we also acknowledged these materials could not substitute for talking directly to computer scientists about the writing they do for work. Below, we describe our study in which we held these discussions with computer scientists with the aim to prepare writing tutors to help computer science majors.

Methods

We used surveys with students and interviews with professionals to develop a tutoring program tailored to computer science majors.[3] The quantitative phase of the study included a survey administered in eight undergraduate computer science courses during fall 2017 and spring 2018 semesters. Students enrolled in these classes were invited to participate in this IRB-approved study (IRB Log No. 17-245). Although one risk of an in-class survey is that students may feel compelled to participate, we mitigated this risk by asking the professors to leave the room so students could opt out and record their responses confidentially.

Participants

The qualitative phase included semistructured interviews with 27 professionals at various institutions throughout the United States and one in Australia. Using a snowball sampling approach, graduate students and graduate assistants contacted the first potential interviewee, explained the study's purpose, emailed the informed consent and interview questions, and set an interview date. Then, each interviewee provided the name and contact information for another potential interviewee, which enabled the participants' social networks for recruiting additional participants. The goal was to recruit participants actively involved in cybersecurity, even if their job title did not contain the word *cybersecurity*. Participants' specific duties were gleaned from responses to three questions: How would you describe the nature of your job? How would you describe the kinds of writing you do most often? Which academic or technical writing skills are challenging for you? Graduate student

3 The instruments, including the survey and interview protocol, are available at https://www.iup.edu/math-computer-sciences/events/cae-c-expansion/research-study/. Resources and assignments, to be discussed later, are available at https://www.iup.edu/math-computer-sciences/events/cae-c-expansion/writing-and-communication-skills-tutoring/

researchers transcribed the interviews and removed or disguised all identifying information.

Table 1
Participants' Pseudonyms, Job Titles, and Duties

Participants	Job titles	Duties
Jordan	Federal government inventory systems trainer	Responding to security issues involving disclosure and systems; inventory-control implementation and training; report writing; compatibility
Jove	High school IT teacher	Teaching how to build and repair computers and devices; programming and troubleshooting
Luke	Faculty tech support	Managing educational technology for science, medicine, and health faculty; educating users about web and email security
Shawn	IT systems operations	Maintaining systems for training and design for online courses
Zoe	Network administrator	Managing, securing, and configuring wired and wireless networks
Daewoo	Information-systems technician	Working with switches, patch panels, server closets, Microsoft exchange, active directories, and a medical-record system
Dinah	Technology-support analyst	Troubleshooting users' problems and questions; educating users about cyberthreats
Sho	IT professional	Monitoring security issues for his organization's use of external websites
Drebor	Director of information systems	Overseeing IT for hospital staff; compliance with HIPPA regulations; third-party vendor updates
Nedrick	Systems administrator	Maintaining servers and equipment; configuring firewalls and routers
Mort	IT cybersecurity for a large bank	Transmitting secure files and records
Josh Smith	System administrator	Using systems and processes to support customers and prevent information theft

Noman	Law enforcement	Securing and using information and technology
John	Cybersecurity for a nonprofit organization	Maintaining user logins and authentication
Tukar	Computer technician	Consolidating domains, especially for account access, active directory, and customer service
Claude	Systems engineer and software developer	Installing and maintaining computing infrastructure, servers, and storage; designing patches and access; writing software
TK	Network administrator	Deploying patches, updating software and antivirus protection; preventing intrusion; managing vendors
Holly	Chief IT officer and administrator for networks and telecommunication	Providing network and end-user security
Raqa	Chief technical support for school district	Supporting hardware, software, and compliance; securing student and personnel information
Barry Allen	Software engineer	Writing and fixing software; reducing vulnerabilities
Lennon	Senior security engineer	Setting up and maintaining defensive infrastructure; preventing theft
Alberto	Senior application developer	Building and running applications for Microsoft .NET and MVC framework; supporting applications to recruit research participants and track progress for clinical studies; applying patches and monitoring audit logs; authentication
Brad	Intelligence analyst	Gathering malware samples, running them, and reporting to law enforcement; monitoring social media for threats
Mace	IT security manager	Working with user-management vendors; monitoring for vulnerabilities and checking logs
Jackson	Senior director of information systems	Managing information for senior-living networks; phishing and spam

Jasmine	Cybersecurity for the military	Patching and preparing documents for certification and accreditation; jailbreak systems
Jaday	Software engineer and project manager	Writing and reviewing code, writing technical documents, and bug tracking; responding to threats

Coding and Analysis

We read the transcripts independently to familiarize ourselves with the data set, and then we met to create a code book (Bernard, Wutich, & Ryan, 2017). We followed Herbert Rubin & Irene Rubin's (2011) *Qualitative Interviewing* (3rd ed.) as a guide. We also generated a list of key terms from the research question and the literature of the field, such as *tech-ese*, *incident report*, and *grammatical error*. We are aware of and agree with Rosina Lippi-Green's (2012) work that details how an obsession with "error-free" writing serves to "discriminate against speakers of stigmatized varieties of English" (p. 84). However, because participants in our study frequently discussed grammatical errors and used the term *error* to do so, we use their word choice throughout this study. Drawing on our participant interviews, we define *error* in this study as departures from style-manual-based conventions (e.g., in the areas of grammar and mechanics), as well as inaccurate information or data. Next, we collaboratively coded one transcript using the initial list of codes, adding to and modifying the list as needed. We then hired two individuals familiar with qualitative data analysis and writing centers, but not with the research study, to code the transcripts.

We created a set of coding instructions for the coders using the initial codebook and examples from the coded transcript. The coders worked independently and then together, using turns as the unit of analysis, modifying the codebook during the process, and making all decisions by mutual agreement. If both coders were unsure about whether to apply a code, they did not apply it. They settled disagreements using evidence from the turn, but if the coders were unable to agree, the code was not applied. The coders checked their agreement for each turn before proceeding to the next. When the coders finished, the researchers read the coded files and made minor changes to improve accuracy and consistency.

Finally, we (the researchers) identified patterns and themes. To move from codes to themes, we each read the coded transcripts independently and then met to review the codes in relation to the research questions and possible themes. For example, we discussed potential overlaps between the codes *audience awareness* and *technical writing*, agreeing that both codes relate to audience awareness since the data coded to technical writing were about writing for technical and nontechnical audiences. We also noticed that *feed-*

back and *support* were separate codes, but our review of the transcripts found that participants spoke of feedback as a particular kind of support; thus, we combined these codes to create a theme. Below, we present the results of our analyses of the survey and interviews.

Results

Quantitative Survey Results

During fall 2017 and spring 2018, 203 students in undergraduate computer science classes at two different institutions completed a survey about their future careers and beliefs about writing (Table 2). The results showed these students aspired to careers in fields such as software engineering and website development, cybersecurity, actuarial science, computer programming, military service, conservation research, telecommunications, and teaching. The participants were overwhelmingly male (78%) and upper-level undergraduates (32% seniors, 28% juniors, 28% sophomores, and 12% freshmen).

Survey questions asked about participants' writing beliefs and practices. Responses to question 1 in Table 2 show more than 90% believed writing skills to be essential for school and career. The responses to questions 2 through 8 indicated most students felt confident about their writing: students believe they use sources without much difficulty, write effectively for readers who do and do not have technical knowledge, get good feedback, and use feedback to improve. Students' high levels of agreement about confidence in writing skills were complicated by what interviews with professionals said because professionals did not express high levels of confidence in personal workplace writing skills and in fact pointed to challenges related to audience and feedback.

Table 2

Survey Results About Writing Beliefs and Practices and Participants' Levels of Agreement.

Writing beliefs and practices	Agreement	Mean	Standard deviation
Good writing skills are essential for success as a computer science/cybersecurity student and professional.	91.8%	5.89	1.04
I find it relatively easy to use information from sources in my writing.	82.2%	5.46	1.19
I write effectively for people with technical knowledge of my field.	80.7%	5.22	1.13

I write effectively for people without technical knowledge about my field.	77.4%	5.12	1.31
People who have read my writing (coworkers, teachers, professors, etc.) say my writing is clear.	75.9%	5.43	1.22
I use feedback to improve my writing.	75.8%	5.56	1.14
I seek feedback about drafts of my writing.	71.4%	5.13	1.39
I use proofreading techniques to ensure that my writing has no errors.	71.0%	5.30	1.24

Qualitative Results

To answer our research question about computer science professionals' communication challenges and skills, we identified the most frequent codes and then developed four themes that describe the perceptions and present skill level and challenges of participants: 1. feedback and support; 2. audience; 3. writing; and 4. ethos.[4] Below, we present our results and examples from the transcripts to illustrate each theme. To show how we drew inferences/themes from our raw data, we provide a sample in Table 3 of a code and its definitions applied to the transcripts. The table lists the number of times the code was applied to a turn (Mentions) and the number of participants these references apply to (Participants). For the full list of codes, please see Appendix.

Table 3

Coding Scheme: Sample Code, Subcodes, Definition, Frequency, and Examples

Codes	Subcodes	Definitions	Frequencies (Mentions/ Participants)	Examples
Feedback and support		Help on and resources for communication skills at work and beyond work	243/25	"It helps getting a second pair of eyes on *there* to read it and see." (Brian)

4 Although not the focus of this report, interviews with professionals also focused on genres used in computer science-related workplaces and challenges with public speaking/ presenting. The most frequently used genres are 1. email; 2. presentations; and 3. documentation, as reported in Table 3.

	Writing center	Reasons for visits/nonvisits, perceptions toward the writing center during/postcollege	65/21	"Looking back, you know, as much writing and presentations as I've done throughout my career, it probably would've been helpful [to go to the writing center]." (Alberto)
	Self-review	Using spell/grammar checkers, proofreading techniques, etc. to correct, rephrase, or change a text	25/13	"I first type a rough draft in Microsoft Office then use spell check and grammar punctuation programs to make sure it's properly formatted." (Jackson)
	Informal coworker feedback	Voluntarily seeking feedback from coworkers on writing	13/9	"I was producing training documents that I was sending out to our users. I had my colleague review it since he's more knowledgeable from the business side than I am." (Josh Smith)
	User feedback	Receiving feedback from the intended end user/customer, or a proxy for the end user, about one's writing	3/2	Interviewer: "Can you describe a time where you produced something for your colleagues, and they did not like it?" Participant: "Plenty of times, whenever I used too much technical language and did not know why they were using the technology tool." (Jordan)

	Company review process	A formal review process for writing that is part of the institutional culture or job requirement	3/2	"If I'm writing something, I'm not the only person to see it. It will go through like three or four people at least before it actually goes out to a partner over one of our distribution channels." (Brian)

Feedback and Support

Twenty-five participants (243 references) spoke to the challenge of finding feedback and support for their workplace writing, making feedback and support the challenge interview participants identified most often.

Writing Center. Twenty-one participants (65 references) responded to interviewer prompts about writing centers. These participants wished they had visited the writing center when in school. For example, Alberto said, "Looking back, you know, as much writing and presentations as I've done throughout my career, it probably would've been helpful." He said if he had gone to the writing center and practiced his writing in college, he "could've came in as a stronger employee," but as an undergraduate, he was focused on "trying to be the strongest technical person . . . and not really thinking about all those other skills."

Not every interviewee felt the writing center could have addressed their needs. Lennon said he did not feel he needed the writing center but then added, "Get people in there that know the technical side of things." Jaday also did not visit the writing center and said, "I never really felt like, oh, I'm really stuck with something."

Participants also mentioned ways to increase writing center visits by computer science students. Alberto said, "The English class I took, it was recommended to go over to the writing center, but I don't remember it ever being encouraged from the computer science professors." Jackson felt computer science assignments could motivate students to seek help from tutors by requiring "improved writing and communication." Other participants recommended highlighting the writing center on the syllabus and having class visits from tutors with technical backgrounds. Another participant emphasized computer science students need to understand the communication skills required in the workplace and suggested professionals visit courses in order to recommend visits to the writing center.

Finally, some participants mentioned they could not visit the writing center due to schedules and availability. Nedrick said, "My computer classes were from like 11 o'clock until 5 or 6 o'clock in the afternoon and it wouldn't be until noon the next day that the [writing center] office was open, so the hours didn't really mesh with my major." Shawn needed access to online resources and wished his writing center offered virtual sessions.

On the Job. Beyond speaking about the writing center, participants in this study also discussed seeking feedback on their writing at work, including self-review (using grammar checkers), conversations with coworkers, feedback from end users and customers, or a formal review process.

Self-Review. Thirteen participants (25 references) spoke of self-monitoring their writing, making self-review this data set's most frequently referenced workplace feedback strategy. Raqa, an IT support professional who helps students and teachers in a public-school district, said about sending an email, "Sometimes I draft it up two or three times and let it sit before I send it because I don't want to assume anything. I want to make sure I'm giving the right information." However, because revisions must be made quickly, six participants (seven references) mentioned technology-mediated proofreading, including using grammar checkers, spellcheckers, and word counts to revise for clarity and conciseness. Jackson, a director of information systems for a senior-living network, uses Microsoft Word to address grammar issues such as passive voice. Nedrick, a systems administrator, said, "If it's an important email I'll usually Google a grammar checker and just post it under the first one that comes up." Nedrick also said, "My spelling is pretty bad, so I do use spellcheck on Outlook."

Informal Coworker Feedback. Nine participants (13 references) said they seek feedback informally from coworkers, from rehearsing presentations to puzzling over emails. Alberto, a senior application developer, said:

> I had a colleague, so we were doing a large presentation for a large client and basically he spent many, many, many hours going over my section of the presentation until he was happy with it. And the next day when we presented it, I spoke and knew exactly what I was talking about.

Brad, an intelligence analyst, said about his coworkers, "We all sit really close to each other. So just to yell over the wall and say, *hey, how would you say this*, you know, we can collaborate a little bit." Lennon, a senior security officer, described a process for email writing: "Sometimes [I'll] even send it to my boss or another coworker to review it for me before I send it off."

Company Review Process. Two participants (three references) discussed formal reviews of their writing. For example, Jaday, who writes articles, gets high-level feedback from "a whole team of editors." She said the editors may address the subject matter, topic, organization, and writing style.

Audience: Technical and Nontechnical Language

Twenty-two participants (112 references) pointed to audience awareness, or the ability to communicate within and across diverse audiences, as a challenge. In the data set, using technical and nontechnical language that is appropriate, accurate, and understandable for the audience is described as particularly difficult. Alberto said he struggles with audience in email messages: "It's always a balance of trying to not be too technical but give enough details what happened." Jaday said her editor critiques her website articles for being too technical and encourages her to use a more narrative style. Drebor, a director of information systems for a small company, uses "laymen's terms" when talking to clinical staff but must "be more technical" with colleagues in the IT world.

Writing Skills: Style and Grammar

Seventeen participants (37 references) discussed challenges with style and grammar. Luke writes teaching materials, documentation notes for users, and academic research articles. When describing a time he struggled with his writing, he pointed to his writing style: "[My tone] wasn't salesey enough, it wasn't markety enough, it wasn't sexy enough." Jordan, who worked for a federal agency as an inventory systems trainer, tied writing grammatically to credibility: "When I look back and see the lack of grammar use in my emails and writing, it is embarrassing."

Ethos

Ten participants (20 references) spoke of the challenge and importance of establishing credibility as a writer. Daewoo, an information systems technician, echoed the sentiment that surface-level issues affect credibility: "I always try to make sure it is spelled correctly. Because that just looks horrible, at least to me, when somebody is writing on something, and you're just like, *What?!?! What position is this person in*?" Daewoo not only questioned other people's credibility based on their poor grammar, but he also worried about his own credibility. When describing a time he wasn't satisfied with his own writing, he said, "It's usually, 'Dammit, why didn't I read that back through again before I sent it out?!'" Chuck observed, "We want to make sure to maintain a professional air [with customers] about the emails."

At the same time, participants also linked ethos to applying technical know-how. As we saw in a comment already quoted above, Raqa said, "I draft [an email] up two or three times and let it sit before I send it because I don't want to assume anything. I want to make sure I'm giving the right information." She also described a time she provided inaccurate information in an email to her supervisor:

Later on that day when I looked at what I sent, I realized how bad it was.

> And I used my phone to send the email, so what I did was reply back to him that I would get him the data again in a better format, so I reorganized and resent the email.

Here, Raqa links ethos to the clear and accurate organization and presentation of data. In another example, Raqa links accuracy to her professional identity: "I do not want my emails to sound like my texts . . . an email to me should still be professional in this day and age." The idea of professionalism was echoed by Barry Allen, a software engineer, who described a time his colleagues were dissatisfied with his writing: "I just feel like they knew I knew what I was talking about, but . . . it appeared rushed, maybe the word selections weren't good, you know, well placed, and the grammar, maybe you made some grammatical errors." While we cannot know the degree to which he felt his professional credibility extended beyond his writing to his knowledge of software engineering, he clearly recalled the time his colleagues critiqued his diction, organization, and grammar and had to encourage him to improve his writing.

Discussion and Recommendations for Writing Centers

We now return to a question posed earlier: What writing challenges will computer science students face after they graduate, and how can writing centers prepare these students for these challenges while students are still in school? Our findings suggest there is a gap between professionals' assessment of the writing demands of the workplace and students' self-assessment of their ability to write effectively.

Professionals Write for Diverse Audiences: Implications for Specialist/Generalist Tutoring

Professionals attest to the need to balance communicating technical information within and across diverse groups through writing, speaking, reading, and listening. Based on our data set, the challenge is how to juggle technical know-how with the audience's familiarity with the subject matter. Ironically, in our study, students, who, of course, have less technical knowledge, expressed high levels of agreement that they write effectively for people with (81%) and without (77%) technical knowledge about their field. We believe this confidence has implications for the question of specialist/generalist tutors. As Sue Dinitz & Susanmarie Harrington (2013) found, disciplinary expertise allows tutors to use specialized discourse to facilitate more effective tutoring sessions. Given computer science students' relatively high confidence, disciplinary insiders may be needed to establish a working relationship. On the other hand, computer science students, like the engineering students Craig (2016) writes about, begin as outsiders to their disciplines and have few prior experiences with writing in their major. Since most tutors, with the support of writing

center training and resources, have made or are undergoing a similar transition from disciplinary outsider to insider, it may also be the case that generalist tutors can relate to the difficulties computer science students face with joining a discipline and can share ways to overcome these difficulties. More research is needed on this possibility.

Grammar and Style: Juggling Lower Order/Higher Order Concerns

In our study, seventeen professionals (37 references) expressed difficulty with grammar and style. Professionals' concerns about their own writing skills indicated that, when it comes to the workplace, style—including tone and conciseness—is important. This finding has implications for tutoring policies that divorce higher order concerns from lower order concerns. Writing center scholars have challenged this binary (Clark, 1990; Cogie, 2006; Min, 2016; Rafoth, 2015; Thompson, 2009), and our data suggest lower order concerns can sometimes be the higher priority, as Maggie Herb (2014) found. Our results are in line with Bethany Bibb's (2012) findings on holistic approaches to teaching and tutoring; Bibb recommends tutors "explain the errors and corrections in terms of content, style, or other elements" to help students develop a "balanced and holistic understanding of writing" (p. 99). Professionals in our study indicated concern about style and clarity, suggesting that in computer science workplaces, accuracy, credibility, and professionalism are reflected in the textual features of written work as well as in the data and information being generated. Participants in our study who spoke about achieving a professional tone in email messages confirmed studies that show email is particularly challenging (Byron, 2008; Levinson, 2010; Wolfe, Shanmugaraj, & Sipe, 2016).

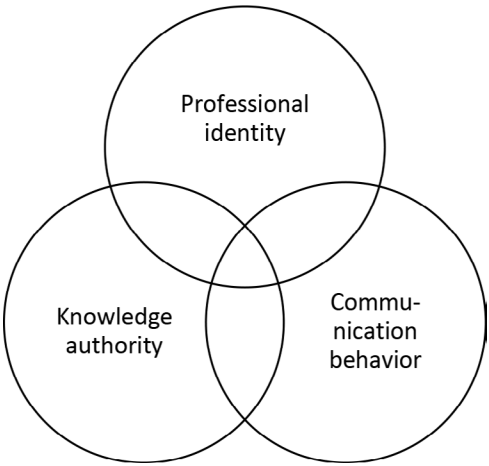
Ethos: Professional Identities, Communication Behaviors, and Knowledge Authority

Among the professionals we interviewed, we found ethos, or the credibility readers perceive about writers and speakers, to be a major concern associated with 1. their professional identities and status in their field or institution; 2. communication behaviors, or speaking, writing, reading, and listening in contextually appropriate ways; and 3. knowledge authority, or the participant's ability to accurately apply technical know-how to solve problems in the workplace.

Evidence for professionals' linking of ethos with their professional identities was marked by their use of emotion-laden words such as "embarrassing," "horrible," and "dammit." These findings align with what compositionists know well: writing is linked to identity (e.g., Adler-Kassner & Wardle, 2015; Ivanič, 1998). As Kevin Roozen (2015) writes, "Through writing, writers come to develop and perform identities in relation to the interests, beliefs, and values of the communities they engage with" (p. 50). For example, our participant

Daewoo regarded spelling errors as a reason to question someone's job qualifications: "*What position is this person in?!*" Such attitudes toward error are also in line with Larry Beason's (2001) findings that professionals tend to see spelling errors as part of a problem that reaches beyond the text to the writer as a person. Our participants also associated their knowledge authority with writing accuracy. Raqa was unwilling to let stand the poorly organized and unclear data she had sent to her supervisor and sent it again after correcting the earlier problems. These findings suggest that professionals' ethos is comprised of related and overlapping domains of professional identity, communication behavior, and knowledge authority.

Figure 1
Components of Computer Science Ethos



To the extent that readers tend to react to some errors more than others (Beason, 2001; Bibb, 2012; Connors & Lunsford, 1988; Hairston, 1981; Rifkin & Roberts, 1995; Sloan, 1990), tutors who help writers identify different kinds of errors and readers' varying sensitivities to errors will be better positioned to address writing behaviors that affect the writer's professional identity and knowledge authority. Equally important, however, tutors must be aware of the racialized nature of many writing errors and the influences of context on what constitutes error. Tutors must learn to reflect on their conversations with writers about errors and these conversations' implications for stereotyping and discrimination (Barron & Grimm, 2002; Blazer, 2015).

For this reason, our findings suggest that a challenge for writing centers involved in tutoring students preparing for computer science workplaces is the tension between the ethos among professionals that writing errors are unac-

ceptable and the long-standing underrepresentation of women and minorities in computer science, in particular, and the tech industry generally. According to the National Academies of Sciences, Engineering, and Medicine (2018),

> Underrepresentation of African American and Latino/Latina workers in the tech industry compared to the U.S. workforce as a whole, accounts for 7 and 8 percent of tech workers, respectively, compared to 12 and 16 percent of all U.S. workers. The gap is even larger for women, who represent only 28 percent of the tech workforce compared to 47 percent of the overall labor force. (p. 91)

The lack of representation of African American, Latinx, and female workers in the tech industry might be why "errors" are perceived as especially problematic in computer science. In his study of writing centers, Asao B. Inoue (2016) writes that they are limited by "male-centered, heteronormative, white, middle class educational systems and language norms" (p. 94). In other words, the fact that ethos is so tied to writing errors in computer science likely results from the lack of diversity in computer science. Possibly, too, the connection between ethos and error might be responsible for the underrepresentation of women and minorities, as these individuals may be viewed as lacking professional ethos because of their departures from hegemonic language norms.

As we mention earlier, the positive side is enrollment in computer science courses is growing rapidly. This means departments have an opportunity to increase diversity. Doing so will require a concerted effort at many levels. Considering professionals' experiences with writing in the workplace and the implications of error for their ethos (see Figure 1), tutors should recognize ethos affects one's professional identity and can be compromised by departures from what some might call Standard Written English*[5] (SWE*), as these departures may be perceived as writing errors by readers enculturated into SWE*—readers who may be the majority of computer scientists.

In the literature on race in writing center studies (e.g., Barron & Grimm, 2002; Denny, Mundy, Naydan, Sévère, & Sicari, 2018; Greenfield & Rowan, 2011; Inoue, 2016), a 2019 piece speaks to the challenge we describe here, namely, educating tutors about the racial dimensions of standard language ideology. In a special issue of *Praxis: A Writing Center Journal* devoted to race and the writing center, Dan Melzer (2019) reports on an action-research project

5 The term Standard Academic English* (SAE*) is used to describe English syntax, grammar, and lexical choices defined as "correct" by writing manuals. SAE* is problematic because it reflects attempts to standardize language and control variation and because the motivation behind placing such constraints on language is rooted in often subconscious or unarticulated racial biases (Lippi-Green, 2016). Rosina Lippi-Green (2012) uses an asterisk to mark SAE* to remind readers SAE* reflects implicit structural bias.

with his predominantly white tutoring staff that led to discussions of race and tutoring and changes to his pedagogy to address white privilege:

- "Connecting issues of language, power, and race to each aspect of the course and not isolating these issues in a single day devoted to language diversity" (p. 39);
- "Scaffolding discussions of white privilege from the first day of class" (p. 39);
- "Integrating more diverse perspectives in class readings" (p. 39);
- "Forcing tutors to confront white privilege in direct ways (p. 40);
- "Making space for both intellectual and emotional discussions of white privilege" (p. 40).

Melzer writes that as a consequence of these changes, "[He] found that tutors became more reflective about their biases and more critically aware of issues that diverse student writers encounter in their initiation to academic discourse" (40). We note, along with Melzer (2019), that white privilege is also an institutional problem, one that requires a coordinated effort among writing centers, academic departments, and allies in WAC/WID, student affairs, and equity and diversity offices. Beyond these confines, and given the imbalance in racial diversity in the tech industry generally, writing centers and writing center scholars might monitor projects in the tech world to address racial imbalances (Muro, Berube & Whiton, 2018) and to look for opportunities to align with efforts already underway.

Feedback-Seeking Behaviors: Perceptions of Writing Centers

The career professionals in our study said they wish they had sought feedback on their writing when they were in school and that now, on the job, they seek feedback out of necessity. None of our participants reported visiting the writing center in college, citing overconfidence, the incorrect perception that the writing center does not serve computer science majors, and scheduling conflicts. Most troubling to us as writing center directors was participants' perceptions that writing centers do not help students in technical fields. One participant, Mace, admonished, "Make sure that the writing center is able to help folks with technical writing." This finding aligns with Salem's (2016) argument that nonvisits to the writing center warrant investigation, and with Harry Denny, John Nordlof, & Lori Salem's (2018) recommendation to be explicit about tutors' expertise, particularly for students who, like ours, often come from working-class and rural backgrounds. Our findings suggest writing centers must prioritize students in applied majors, such as computer science, by helping with the issues that concern students, including grammar and proofreading. The fact that two professionals said they wish they had been required to visit the writing center suggests a reason to continue to explore the

benefit of required visits. (For a review of the literature on required visits, see Rachel Azima's article in this issue.)

Training a Team of Computer Science Writing Tutors

From what we learned from the surveys and interviews, we then had a limited amount of time to prepare tutors to help students with their computer science writing assignments. To do this, we worked closely with our colleague in the computer science department to train and lead a team of six writing tutors to assist cybersecurity-focused computer science and criminology majors. The team included both generalist and specialist tutors majoring in computer science, biochemistry, biology, criminology, anthropology, and English. Below, we describe how the special team of tutors were trained so that readers who wish to emulate this training can benefit from the work we did.

During the academic year, the tutors completed 13 hours of studying writing assignments, checking student learning, and conducting synchronous online tutoring. These hours were aimed at increasing tutors' confidence and competence during computer science writing tutorials. Tutors learned to interpret assignments, adopt stances of technical versus nontechnical readers, and help students develop knowledge about style, mechanics, and punctuation. Further, as we gathered data about the communication challenges professionals face, we shared this information with the tutors. In sum, we took the following steps to train tutors:

- Familiarized tutors with the discourse of computer science writing assignments by sharing assignment sheets provided by computer science faculty;
- Engaged tutors in general training, such as how to conduct an online session effectively;
- Asked tutors to create resources for computer science students, which required tutors to research disciplinary expectations.

One goal we set for these computer science tutors was to familiarize them with some of the genres and technical language used in computer science courses, following up on interviewees' requests for tutors with technical knowledge. To facilitate this training activity, we met with computer science faculty to request copies of their assignments and rubrics, which we later reviewed with the tutors during a training session. The tutors then compiled questions for the instructors; the instructors responded to Krista, the training coordinator, and shared their expectations for writing in the assigned genre. Then, in a follow-up meeting with tutors, Krista informed tutors of instructors' expectations for the writing assignments. This component of the training, sharing and analyzing assignments, elevated the tutors' confidence and credibility when tutoring.

The second component of our tutor-training program equipped tutors with the knowledge of online-tutoring practices, which may be thought of as general training rather than computer science-specific training. Because the interviewees indicated professionals did not visit the writing center when they were in school due to logistics and convenience, we made tutoring accessible to more students. We opened a link, exclusively for computer science majors, to our online writing center and trained tutors to use the platform for synchronous tutoring. These majors also learned to use help sheets and links from the resource library we created and stored online. Eventually, each computer science student scheduled at least one 45-minute synchronous appointment with a computer science writing tutor, for a total of 74 sessions in all—but only after a professor required the writing center visit as a part of a graded writing assignment.

The third component of our tutoring training involved working with tutors to create videos and handouts. By the end of the grant period, tutors had modified 24 handouts and created eight videos about writing, using examples, descriptions, and scenarios familiar to computer science writing. In doing this, the tutors not only created useful resources for writing in computer science but also gained a modicum of disciplinary knowledge. The handouts and resources tutors created are housed online and available for public use.

Limitations

One of the challenges we faced when designing our tutoring program was measuring the effectiveness of sessions. While this was not required for the grant, we wanted to know for our own sake what effect tutoring had on the group. We knew, for example, that tutors were unlikely to increase writers' confidence because the surveys showed student-writers had plenty of that already. Using short pre- and posttests with objective-type questions, we therefore tried to measure gains in rhetorical knowledge such as tone, word choice, and organization. We thought the tests might also help focus the sessions because students did not always have a clear sense of purpose when visiting the writing center. Tutors found these assessments awkward to use, however, and told us that, as tutors, they did not like the idea of "giving a test." Most tutors did not use the assessments, and we abandoned the idea. In retrospect, we needed to find a better way to assess the sessions. Further, the project had to be completed in nine months, leaving little time to conduct the surveys and interviews, coordinate with faculty and get buy-in, recruit and train tutors, and develop materials. With more time (and the same funds), we might have been able to learn whether tutoring had a measurable impact.

It is also worth noting that while our writing center was tasked with enhancing writing instruction, tutoring cannot substitute for disciplinary-writ-

ing instruction for computer science students. We hope our experience offers a jumping-off point for writing centers seeking to help students be ready for professional challenges, even when those students receive inadequate writing instruction in their disciplines. Because our writing center enlisted faculty allies, we were able to help faculty design writing assignments for their courses, and we were able to prepare tutors to work with students completing these assignments. Although our writing center engaged in activities typical of writing in the disciplines, we found that aligning with computer science faculty began important conversations in the department about tutoring, student writing in faculty members' courses, and how those of us with writing expertise could help. Thus, writing centers might look at our experience and use it as a foundation to build relationships with their own computer science departments—not to take on the responsibility of teaching computer science students to write in their field but to open cross-disciplinary discussions about how to prepare undergraduate majors for writing they will probably have to do after graduation.

And finally, because this study relied on self-reports from a small sample of students and professionals, we are cognizant that participants' perceived communication challenges may differ from their actual communication challenges and may not represent the full scope of communication challenges faced. In particular, our finding that traditional notions of error hold sway among the participants in our study may or may not apply across the field of computer science. Attitudes toward error in the field in general deserve further study because of their implications for correcting imbalances in the racial and gender makeup in computer science.

Conclusions

We learned a number of things about the challenges computer science students are likely to face after they graduate and how our writing center can address these needs, based, first, on the data gathered from professionals and undergraduate majors, and second, on our experience implementing a tutoring program for students. First, from the professionals, we learned they write far more often than they imagined they would when they were in school and now must often balance communicating technical versus nontechnical information within and across diverse groups. The challenge professionals face is how to juggle technical know-how with the audience's familiarity with the subject matter. On a related note, we learned the terms *technical* and *nontechnical* are relative and highly dependent on context. For example, some of our participants described the writing they do as documenting internal operations to ensure accuracy and consistency, both for themselves and for those who will succeed them when they are absent or leave the job. In this case, participants

write as one technical person to another, and the challenge is nonetheless to write accurately and clearly, adjusting their sights each time for audiences that have different types and levels of technical expertise. In other words, professionals write for audiences that do not break down easily into the categories technical or nontechnical. Audiences can be both or neither.

Second, from the students, we learned that when their professors required them to visit, they showed up, and tutors could apply their specialized training. Support from the faculty proved key to making student visits worthwhile and was probably at least as important as what the tutors did in their sessions.

Third, the results from our quantitative and qualitative data, our discussions with computer science faculty, and our readings of the field's literature all point to the high value placed on accuracy and precision in computer science and the relatively low tolerance for errors, whether these pertain to coding software, analyzing cyberthreats, or communicating in writing or speech. Among computer scientists, errors are generally considered bad, in whatever form and wherever they occur. It is safe to say computer scientists do not recognize what Joseph Williams (1981) called "the phenomenology of error." Learners' developmentally related writing errors seem not to be as tolerated in computer science workplaces as these errors are in writing centers and writing classrooms. Except perhaps for unreasonable deadlines and low-stakes work, errors of all kinds tend to be associated with work that is unsatisfactory at best and careless and lazy at worst; the credibility of those who produce errors tends to suffer accordingly. We believe this attitude toward error will continue to pose challenges for writing centers and computer science departments seeking greater diversity and inclusion among students served.

Through this study, our writing center began to reflect on existing and possibly ineffective pedagogies and dichotomies, such as the dichotomy between discipline-specific and general writing tutoring, between higher order and lower order concerns, and between the terms *technical* and *nontechnical*. Future research might inquire into the texts computer scientists write, why they are writing them, and who is reading them; in particular, future studies might try to unravel issues of error in computer science and understand which errors have implications for ethos and which errors have implications for accuracy. With a nuanced understanding of the kinds of writing valued in applied fields like computer science, and the challenges undergraduates will face when they enter computer science workplaces, writing centers can better prepare students and tutors for these realities.

Acknowledgments

We would like to thank Dr. Waleed Farag, principal investigator, IUP Department of Mathematics and Computer Science, Dr. Mac Fiddner, co-PI, IUP Department of Political Science, and Dr. Crystal Machado, IUP Department of Professional Studies, for their support of this project. Additionally, we thank Havva Zorluel Ozer and Melissa Lutz for their assistance with data analysis.

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Appendix

Coding Scheme: Codes, Subcodes, Definition, Frequency, and Examples

Codes	Subcodes	Definitions	Frequencies (References/ Participants)	Examples
Audience		Challenges with communicating within and across diverse audiences	112/22	"One of the biggest things is making sure you're speaking or writing in a way that you're talking to the audience at that level." (Brad)

	Technical and nontechnical language	Using language the audience views as appropriate, clear, accurate, and understandable	24/12	"You do not want to list a bunch of acronyms or technical jargon when presenting it to someone who doesn't understand it." (Sho)
	Writing skills	Challenges with skills such as tone, style, and conciseness	37/17	"Both grammar and clarity [are important]." (Jasmine)
	Grammar	Challenges with making grammatical choices that project clarity, accuracy, and professionalism	19/9	"When I look back and see the lack of grammar use in my emails and writing, it is embarrassing." (Jordan)
	Style	Challenges with issues of tone, word choice, and other stylistic choices	3/3	"I am more succinct now. Developed over time. I was too verbose in the beginning." (Jordan)
	Ethos	The credibility readers perceive about writers and speakers	20/10	"I do not want my emails to sound like my texts. Like I don't . . . there's a blur there. It seems that a text message is just a quick question, but an email to me should still be professional in this day and age." (Raqa)
	Presentation skills	Challenges with public speaking and presenting in workplace settings	67/25	"I don't have any trouble talking to people, but being up in front of a group of strangers and talking was very intimidating to me at first." (Zelda)

Types of writing		Genres participants use in cybersecurity work	211/27	"About 90% of the day we're all in communication probably. Really it's probably 75 [writing] slash 25 [verbal]." (John)
	Emails	Electronically distributed messages.	61/24	"About 20% and the most common written communications are typically short emails. . . . Day to day, most of it is short emails responding to this or that event." (Mason)
	Presentations	Spoken delivery of information to an audience	59/25	"One thing I have to do a lot of is making pitches for new technology." (Holly)
	Documentation	A written document with instructions for or a record of a process or procedure	23/11	"I do a lot of documentation on the network for my own use such as every time I put a new computer in." (Nedrick)
	Reports	A written account communicated via an official, formal document	18/11	"We have [reports] for new employees that are on boarded here. . . . Statistics on how well they're doing." (Dinah)
	Training materials	Communiques used to train employees or end users	8/5	"I do a lot of writing in regard to updating training documentation." (Josh Smith)
	Social media	The use of websites and applications to interact with customers, colleagues, or industry peers	7/4	"I've been using a lot of Twitter and YouTube for the purposes of actually training and support for users." (Luke)

Proposals	A written document that communicates a plan, suggestion, or idea	2/1	We'll do business proposals for project-type work that might cost a quarter million dollars." (Mason)

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