Lab Reports and Horror Stories: Exploring Chemistry Majors' Evaluations of Scientific and Creative Writing

Justin Nicholes
University of Wisconsin-Stout

The present study adopted a case-study qualitative design to discover how science undergraduates at one public university in the eastern U.S. understood writing and how they evaluated creative or personal writing in relation to their science identities. Findings suggest that science majors in this volunteer sample defined science writing as distinct from other kinds of writing, but they also saw creative writing as personally enjoyable and valuable. The discussion explores an observation that science educators may be able to leverage creative, imaginative writing to give students chances to demonstrate how creative narratives do not lie beyond the boundaries of scientific discourse, as well as for reflective and writing-to-learn purposes for students.

Key words: science writing, creative writing, writing across the curriculum, writing to learn

Introduction

Research in writing studies has suggested that U.S. college students begin to define writing as mainly subjective and belletristic in high school, and that these definitions remain resistant to change even after students encounter college writing courses emphasizing writing as *situated*—that is, as social action taking place within discourse communities (Swales, 1990, 2017) through genres responsive to rhetorical situations (Bergmann & Zepernick, 2007; Driscoll, 2011). From kindergarten through college, students may encounter messages that frame as commonplace that "writing," perceived principally as a domain of English classes, is subjective and distinct from disciplinary, science writing, perceived in contrast as objective and informative (Martin, 2012). Meanwhile, science-literacy scholars have long advanced evidence-based arguments that adolescents who do not realize the centrality of writing and reading in the everyday life of scientists, as well as how science writing is subject to methodological limitations and societal power dynamics, may have their ultimate success or motivation to study science stymied; in other words, the success of science students may partly depend on how they understand *writing* (Shanahan, 2004). Not realizing the centrality of writing and communication may also complicate the college writing experience, such that students fail to notice connections between content explored in first-year composition courses and later, discipline-specific coursework (Bergmann & Zepernick, 2007; Driscoll, 2011). Indeed, in the present case study, while the volunteer undergraduate chemistry majors who participated in this study described science writing as distinct from other kinds of college writing, they also indicated personal investment in both personal and creative writing. This study seeks to provide further evidence of the relevance and motivating capacity of creative and personal writing, often perceived as beyond the realm of science.

Literature Review

In an important writing-across-the-curriculum (WAC) study that rhetorically analyzed more than 2,000 writing assignments from 400 courses across disciplines in 100 U.S. colleges, Melzer (2014) concluded that "poetic [i.e., creative] writing and expressive [i.e., personal] writing were almost non-existent" (p. 104). Melzer's conclusion was not that personal or creative writing should replace writing in the disciplines. Instead, Melzer (2014) described personal and creative writing as comprising "valuable kinds of rhetorical situations" (p. 116). In addition to presenting students with chances to write in, and develop awareness of, the rhetorical situations in which personal and creative writing operate, this kind of writing may promise other benefits for college students.

For instance, creative writing has been described as offering a therapeutic process (Bishop, 1993), and reading of poetry and fiction has been implicated in enhancing understanding of, and empathy toward, others (Djikic, Oatley, & Moldoveanu, 2013; Hanauer, 2003; Johnson, 2013). Far from an activity foreign to scientists and innovators, creative writing occurs in industry and higher education, for instance in the form of science fiction

prototyping (Atherton, 2016; Draudt et al., 2015; Kymalainen et al., 2015). Creative writing has also been linked to changes in persuasive writing performance and writing metacognition (Iida, 2012), and Alshreif and Nicholes (2017) found that students expressed feelings of enhanced metacognition after writing poetry and short stories in the areas of writing-strategy effectiveness awareness and perceived quality of final drafts.

In addition to creative writing impacting students' understandings of others and performance of writing, science educators like Hadzigeorgiou (2016) have emphasized the importance of imagination in STEM education, particularly relating to how narrative writing and thinking foster students' senses of *wonder* toward science (Hadzigeorgiou & Fotinos, 2007). The STEAM movement, defined as "an opportunity for teachers to partner, learn, and teach about the many areas where art and STEM intersect" (Wynn & Harris, 2013, p. 53), suggests how creative writing may complement science education. For instance, in a noteworthy study from Kenyon College, Gillen et al. (2020) argued that students training to become biological scientists both enjoyed and enhanced their science communication skills by writing about science creatively. Further scholarship on scientists and STEM majors writing creatively in the classroom has likewise proved revealing. Emerson (2016) noted that scientists in her study who wrote creatively did not discuss overlap between their creative and science writing. They did, however, discuss ways creative and science writing influenced each other: In particular, both creative and science writing relied on and benefited from the use of metaphor. In another paper concerning STEM students and creative writing, Killingbeck (2006) suggested that permitting students to write creatively and playfully proved to be an effective writing-to-learn technique in field botany and taxonomy. In a study that measured student reactions to creative writing in the classroom, Henary, Owens, and Tawney (2015) investigated whether preparing a lab report with an optional creative introduction affected chemistry appreciation as well as the understanding of chemistry content among non-STEM majors. Excitement and comprehension were boosted when students composed these creative introductions, where students were free to put introduction sections into an imaginative story (Henary et al., 2015). In yet another study, outcomes of introducing creative writing in science classrooms may provide reason for pessimism. Summerby-Murray (2010) addressed whether first-person creative writing in an undergraduate cultural geography class was capable of supporting concept learning. Summerby-Murray described that students were skeptical that creative writing was worthwhile, and students pushed back on the assignment: Students at times derided creative writing, expressed uncertainty about how and whether to use first person, and at times expressed a lack of familiarity or desire to story-tell.

Purpose of Study

To further understand how chemistry majors evaluated scientific, personal, or creative writing, this case study posed the following research question: *When chemistry majors discuss writing assignments and self-*

directed writing activities encountered before and in college that they found meaningful, how—if at all—do they evaluate personal or creative writing?

In defining kinds of writing, I draw on the seminal work of Britton, Burgess, Martin, McLeod, and Rosen (1975), who explained that writing could be understood as *transactional*, *expressive*, or *poetic*. Transactional includes more formal academic writing whose main purpose is, for instance, to theorize, summarize, or report. In the present study, *science* writing as discussed by student volunteer participants falls within the category of transactional writing. Expressive writing, referred to here as *personal* writing, is writing whose aim is to make sense of impressions or feelings. Finally, poetic writing, referred to here as *creative* writing, comprises the writing of signature literary genres including that of poetry and fiction. The aim of the present report is to present qualitative data collected from a sample of volunteer undergraduate chemistry majors at one U.S. public university as they explained their understandings of chemistry-related, *science* writing, as well as writing that is both *personal* and *creative*.

Methods

Research Site and Sample

Reviewed and approved by the research site's institutional review board (IRB), this study took place at a U.S. state public university described as a comprehensive, doctoral/research university. With approval from the IRB, chemistry department, and individual chemistry professors, I visited chemistry lab courses to invite participants face to face and also posted approved invitational fliers on notification boards along hallways in science-major buildings. The department of chemistry that was involved in this study employed approximately 20 full-time faculty members and offered half a dozen undergraduate degrees. The department's chemistry-degree curricula were certified by the American Chemical Society and included undergraduate technical degrees, professional degrees, and degrees with pre-medical, pre-pharmacy, and interdisciplinary tracks. The department also had one professional science master's (PSM) degree with a focus on applied and industrial chemistry. From this chemistry department, seven enrolled undergraduates volunteered to participate. All participants considered and signed informed-consent forms. Table 1 describes student characteristics, with pseudonyms being used.

Table 1

Chemistry Participant Student Characteristics

	Name	Gender	Year	Department	Focus
1	Ada*	Female	First-Year	Chemistry	Biochemistry
2	Arykaj*	Female	Junior	Chemistry	Pre-Pharmacy
3	Kiki	Female	Senior	Chemistry	Biochemistry
4	Linus	Male	First-Year	Chemistry	Pre-Medical
5	Ramsay	Male	Junior	Chemistry	Chemistry
6	Reatha	Female	Junior	Chemistry	Chemistry
7	Rosalind	Male	First-Year	Chemistry	Biochemistry

Note. * = self-selected pseudonym.

It is important to note that this institution had a WAC program. The reason is that research into writing assignments across the curriculum has found that those schools and programs with WAC cooperation offered students greater ranges of rhetorical situations from which to write, including more writing-to-learn (WTL) and writing-in-the-disciplines (WID) experiences (Melzer, 2014). Specifically, according to a taxonomy of WAC programs forwarded by Condon and Rutz (2012), the WAC program at the present research site can be defined as falling between "established," meaning the program mainly supported faculty development, and "integrated," meaning the program also was integrated into assessment, accreditation, and accountability agendas (p. 362). Additionally, the WAC director was also the director of first-year composition courses at the time this study took place--programs which influence nearly all incoming students, and significant focus was placed on offering students rhetorical knowledge related to audience, purpose, and genre.

Procedures

In one-on-one interviews, I asked each participant questions related to meaningful or memorable writing they experienced, mainly in the context of chemistry or science coursework, both from before and while majoring in chemistry at their university (See Appendix A for the interview protocol.) In analyzing transcriptions, I engaged in cooperative coding (Smagorinsky, 2008). This process involved me and one other researcher's negotiations on how to determine units of analysis in transcriptions and which codes might be given to a unit. Units of analysis began and ended whenever a participant's utterances focused on a new theme. This meant units could be as small as one word or phrase and as long as individual clauses. After a session for developing codes and negotiating the transcription of two of seven disciplinary writing interviews (>25% of the data), I created a coding test of units not cooperatively coded. The result of our process was a very high degree of reliability, with an average measure intraclass correlation coefficient of .99.

Findings

Here I present summaries and illustrating excerpts of the seven participants' responses when asked about meaningful pre-college and in-college disciplinary writing experiences. Pertinent to this question were four notable findings:

1. All seven participants discussed science writing as unique and different from other kinds of writing.
2. Of those participants who referred to enjoying creative writing (two of seven), the chemistry major itself was also described as a principally creative endeavor.
3. Four of seven participants described science writing as a way of learning science.
4. Two participants spoke of compelling creative writing both in and outside the chemistry classroom, suggesting perceived value of rhetorical situations for creative writing.

Finding 1: Science Writing as Unique and Different From Other Kinds of Writing

All participants described the writing they did in chemistry classrooms (labeled here simply as *science writing*) as being different from other kinds of writing, such as what they described as humanities or English-class writing. It is important to note that the goal here is not to interrogate definitions of science versus creative writing; rather, the aim is to explore how students themselves explained writing in personal terms.

Ada (first-year student, biochemistry) mentions the nature of lab reports in the context of discussing an honors-college open-ended philosophical writing assignment where she needed to argue for her position on the nature of art (see Appendix B for transcription conventions):

99 ADA [4:40] [Um] (1.0) but yeah I didn't --
100 (1.0) I hated to write in high school.
101 I absolutely hated it?
102 I thought it was a chore,
103 and (.) mostly it was because I wasn't writing the right things?
104 Um and I think it was partly because I (.) wasn't prompted in the right ways?
105 Because high school writing is more of just compare and contrast these two pieces of works,
106 and no one likes to write about that. @@

Here Ada has indicated not feeling especially engaged by high school writing, which felt almost tedious ("a chore" – line 102). Yet Ada also indicates an understanding of the importance of writing assignments, of being "prompted in the right ways" (line 104). As we continued our discussion, Ada discussed a writing assignment she was taking as part of her honors-college student status.

107 ADA: Um but when you have such a large question like core like this unit it's how do we understand art.
108 There's so: many different things to: consider and so many different stances you can take and none of them is wr- none of them are wrong.
109 Um (0.5) but (0.5) when you have an essay like you do in high school or like a lab report you're either right or your wrong and it's --
110 RESEARCHER: [05:23] Ah (.) like the way you're graded or [assessed?]
111 ADA [05:25]
[Yea:h,]
112 yeah it really is, and it's --
113 it's easy to be wrong and it's harder to be right.

Here Ada has outlined qualities of a writing assignment she finds engaging: The prompt asks for personal investment by way of asking students to take personal positions, to make personal connections with a topic. This kind of writing seems to qualify as personal WTL (Carter, Ferzli, & Wiebe, 2007;

McLeod, 1992/2000) writing that prompts personal investment in an issue, in which the author herself is the principal audience. Going forward, Ada continues to discuss how she sees the world and how writing challenges that worldview:

114 ADA: Um and I think I talked last time how I see the world in black and white?

115 But the strange thing for me is that writing is one of the only gray areas (.) that I appreciate.

116 (1.0) Um (0.5) and I really --

117 (1.0) I don't know writing is definitely a concise way to (0.5) um (1.0) put into words my emotions?

118 Which personally I can struggle with?

119 But I journal a lot?

120 And it helps (.) now.

121 Not in high school.

122 But it really --

123 it helps me to understand (0.5) the world around me better.

Ada indicates investment in personal writing, such as in position papers on broad issues like art and journal writing, another WTL experience (Fulwiler, 1982). Of concern above, however, is that Ada describes seeing the world "in black and white," which is also the way she describes science writing in other sections of our discussion (line 114). Yet Ada sees writing, particularly WTL activities, as challenging that black-and-white viewpoint.

Another way participants discussed science writing and thinking as distinct from other kinds of writing they described was by holding up what they described as science writing to humanities-related writing. Linus (first-year student, pre-medical) expresses this in the following excerpt from our discussion:

139 LINUS: [07:54] Just in general I think (.) um it's a very different experience from writing within like the humanities, In that --

140 I don't know how to phrase this correctly um,

141 Just that (1.0) you really have to always reaching out- from my perspective.

142 I realize that you know if I were a humanities I would see it the other way,

143 I would feel like science writing is very simplistic.

144 But I definitely feel like every time I have to go write something I have to go find this other thing that maybe I'm not fully understanding about this aspect of the paper.

145 So it's (.) kind of a like (.) further down the rabbit hole whenever I write it,

146 Which is pleasant in some ways but not always.

Here, Linus refers more to the WID kind of writing done in his major (McLeod, 1992/2000). As such, he notes how humanities-related writing, which according to Ada might present more personal or creative kinds of writing

qualifying more on the writing-to-learn side of the continuum of WAC approaches, differs from science WID experiences. In particular, he notes how WID writing leads him to continue researching or finding further information.

Another way one participant (Kiki, senior, biochemistry) expresses the uniqueness of science writing is by explaining it in terms of what I (the interviewing researcher) am perceived to write:

128 KIKI: [4:54] It was more like (.) focus on giving you feedback so you could by the end of the semester have like a- one good lab report written the right way?

129 'Cause like (.) it is hard to get in the mentality of like (.) lab report writing is not (.) English writing.

130 Like you're not (.) like what you're writing is not what I do @@

This excerpt suggests a view that science writing is distinct from the writing typically done in English coursework. Thus another way participants may present science writing as unique is by comparing it to other kinds of writing.

Findings 2: Chemistry and Writing Are Creative Endeavors

Yet, two participants in particular took steps to express how they saw both writing and chemistry as fundamentally creative. First Rosalind (first-year, biochemistry) expresses creativity in the following section of our discussion:

19 ROSALIND: [00:40] With bio and chemistry they're both like very creative topics?

20 And I've always been like a very creative person.

21 So talking about that kind of stuff came naturally to me (.) if that makes sense?

22 So writing about --

23 like some people would think it's challenging,

24 Because of like the topic.

25 But I really enjoy it because I like (.) - because they're both creative aspects,

26 Like writing and (.) um bio and chemistry.

27 And like (.) putting those two creative thoughts together –

28 I don't know I just thought (.) –

29 I really like writing though.

In presenting herself as a creative person, Rosalind here describes how being in chemistry and enjoying writing should be logically expected. Both chemistry and writing, after all, are creative activities to Rosalind.

In my interview with Ramsay (junior, chemistry), at the very end of our discussion, Ramsay wanted to clarify a misconception about chemistry. In the following excerpt, Ramsay does this by pointing out what to him is a misunderstanding people hold about his major:

433 RAMSAY: [19:00] (5.0) Um- (10.0) I mean (.) maybe uh (.) hm.

434 I guess one of the interesting things about chemistry is,

435 And I guess a lot of sciences is I get the impression that people feel like (.) -
436 whereas say you were in an arts field it's very creative?
437 Whereas in the science fields it's the exact opposite?
438 It's very stifling very (.) analytical there can't be any creativity?
439 What I found is though (.) that especially if you're in the research side of things?
440 There is a definitely a certain amount of creativity.
441 For example (.) the BP oil spill,
442 Like the one person found "Okay we can put this bacteria in the water,
443 "It would eat the oil."
444 It's- you would have to be pretty creative to think of something like that.
445 For a lot of the research-based sciences?
446 You're- they're- you're not just there to observe something,
447 You're there to solve a problem,
448 So you have to often times have to think outside of the box for that.
449 It's just I don't know just something to add on,
450 It's an interesting --
451 looking at people's perceptions of stuff and (.) saying "I'm not sure if that's correct."
452 Like it can be very creative although it is very analytical at the same time.

Here, Ramsay seems to refer to disciplinary writing, or WID experiences, that respond to real-world issues, like oil spills. For him, research is a creative activity, just as creative as other kinds of activities presumably done in other majors, such as art-related majors.

Finding 3: Science Writing Can Help You Learn

A finding pertinent to this paper's research question concerns the way chemistry majors talked about writing as a way of learning. Ada (first-year, biochemistry) succinctly puts it this way:

92 ADA: [04:20] It [writing] really: generates a new kind of thinking.
93 Not just for me but for everybody.

While Ada's response above seems to refer to writing in general for all writers, Rosalind (first-year, biochemistry) speaks about a specific genre, the lab report, that represents a WID experience for her:

105 ROSALIND: [07:00] But for the most part.
106 Yeah we do a lot of writing in chem with the lab reports.
107 And (.) but that really helps you understand what you did in lab though.
108 And it helps you talk intelligently about it to understand the material.

In addition to providing a WID experience, lab-report writing also requires Rosalind to work out what exactly happened in lab. Writing is a thought-generating and thought-clarifying experience.

Finding 4: Chemistry Majors and Creative Writing

As a final noteworthy finding, two chemistry majors pointed out creative writing assignments they found especially meaningful in their educational lives. First, Arykaj (junior, pre-pharmacy) refers to an assignment she had in a high school chemistry class:

91 ARYKAJ: [3:20] Now I will say that one of the funnest assignment I remember that I did in high school was um --
92 okay so in my chemistry class,
93 my professor made us all (.) each pick an element off the periodic table.
94 You could pick whatever element you wanted.
95 You just can't pick the same one as someone else in the class.
96 And (.) we basically came up with a nickname for that.
97 So I- I don't remember what I did?
98 But (.) like let's just say if I did nitrogen.
99 I would call it (.) um Nile Nitrogen or like come up with a fake name for it.
100 And then basically create a character from that element.
101 And then also (.) um (.) --
102 like we had to like actually investigate it.
103 We had to go out and come up,
104 Like I said to come up with a name,
105 And then come up with different characteristics about- about that element.
106 So like if I did nitrogen,
107 Okay I know that nitrogen can be found in the air that we're breathing,
108 So I would (.) incorporate that into the background of the element.
109 And like we actually --
110 it's almost as if like (.) the element was a baby to us or a child and we had to come up with its life story.

While Arykaj above refers to creative writing happening in chemistry class to explore content knowledge, Ramsay (junior, chemistry), who earlier discussed the fundamentally creative nature of chemistry, refers to a creative writing experience in high school English:

32 RAMSAY: [01:50] In tenth grade one of the assignment we had was around Halloween?
33 So we were supposed to make a short story that was scary?
34 And I was writing it and I got really into it?
35 And it was supposed to be seven to eight pages?
36 Mine ended up being 20? @@@
37 And uh @@ I think for five or six days I got up at five o'clock,

38 Two hours earlier than I had to- to write this thing.
39 It was- I really got into it and I didn't like want to like half-ass it I guess.
40 RESEARCHER: [02:15] Was it like a horror story?
41 Or like sci-fi?
42 RAMSAY: [02:19] Yeah.
43 Horror story basically.
44 Um (0.5) that was fun.

This excerpt from Ramsay is the most enthusiastic of all responses to any writing assignment mentioned in the interviews. Nowhere else in the interview data did a participant express the desire to wake up early and write, as if transported (Johnson, 2013) into the writing world.

Discussion

The aim of this report is to present qualitative data collected from a sample of undergraduate chemistry major volunteers at one U.S. public university as they explained their understandings of chemistry-related writing and writing more generally. Specifically, this report focuses on how these students explained chemistry-related writing in relation to other kinds of writing, which was *expressive* (or personal) and *poetic* (or creative) (Britton et al., 1975; Melzer, 2014). To guide exploration, I posed the question, *When chemistry majors discuss writing assignments and self-directed writing activities encountered before and in college that they found meaningful, how—if at all—do they evaluate personal or creative writing?*

Earlier research has suggested that science students may be unaware of how central writing and reading are to scientists' everyday professional lives (Emerson, 2016; Shanahan, 2004), and this perceived division may be exacerbated by messages students in U.S. school systems face regarding "writing" subjects versus science subjects (Martin, 2012). The observation of the present study, it is argued, has been to explore one sample of current science undergraduate volunteers to explore whether personal or creative writing arose in larger conversations about what they deemed to be meaningful writing experiences from before and while in college, where they were majoring in chemistry.

A central conclusion here is that personal or creative writing can serve to build bridges among disciplines. On the one hand, interview data supports earlier research on the ability of creative writing to assist with effective WTL, which is in line with earlier research for field botany students (Killingbeck, 2006). In addition, notably, participants in this study expressed motivation to be creative and write creatively, which further supports earlier studies on the excitement (Hadzigeorgiou, 2016; Hadzigeorgiou & Fotinos, 2007; Henary et al., 2015) and cross-influencing effect of writing both creative and science writing (Emerson, 2016, 2019; Gillen et al., 2020). Melzer (2014) indeed has argued that personal and creative writing offer students practice in engaging with rhetorical situations that, when explicitly understood as occurring within and responding to rhetorical situations, can work to broaden students' understanding of writing as both personal and situated—rather than a

problematic binary of subjective “writing” and more objective “disciplinary/science writing” that may complicate science students’ ultimate motivation to pursue science and be thinkers/communicators of science (Emerson, 2016; Shanahan, 2004).

Additional findings from this study correspond to earlier research instructive to first-year writing pedagogy. For one, that each of the seven chemistry majors interviewed for this study saw their disciplinary, science-related writing as distinct from the kind of writing done in high school and college English classes reflects earlier research on the topic (Bergmann & Zepernick, 2007; Driscoll, 2011). Science writing was unanimously described as unique and comprising, especially, the lab-report genre by all seven participants. Yet, participants showed interest and even personal investment in personal writing (Ada, for instance, in her journaling; both Ada and Linus in their personal-persuasive honors-college writing about the nature of art) and creative writing (Arykaj, Ramsay). That some participants (Ramsay, Rosalind) spoke of writing and chemistry as inherently creative also reflects earlier research, such as Emerson’s (2016) study of scientists’ literacy narratives. Emerson’s (2016) scientist participants saw themselves as engaged in creative activities, with one participant calling scientific papers “creative non-fiction” and many indicating the importance of narrative conventions or stories for science books (p. 156). A pressure to separate personal or creative writing elements in scientific writing, however, was echoed by even the senior, established scientists in Emerson’s study, reflecting perhaps a broader message communicated among scientists who were hoping to train undergraduate and graduate students to enter into scientific discourse communities with the lab-report or IMRaD formula-style genre of writing required for that entrance. This distinction was also found in the present sample of interviews, suggesting the widespread perception of a creative/science-writing divide.

Other findings from this study require further research and exploration for application to science education and writing studies. First, the chemistry students in this study discussed how their lab report writing promoted learning. This finding reflects other WAC research, for instance Carter, Ferzli, and Wiebe’s (2007) research into how lab report writing both supports content learning (as a WTL experience) and socializes students into disciplinary ways of thinking and communicating. Extending this research are findings in this current case study that these volunteer participants in the honors college who were tasked with writing personal-persuasive writing about the nature of art reported that the writing was both engaging and supporting of critical thinking (that is, thinking that eschews so-called black-and-white thinking). Additionally, participants in the current case study who discussed chemistry as a fundamentally creative major also talked about times they felt personal investment in personal writing, creative writing, and writing in general.

In suggesting how science educators may leverage their students’ interests in personal or creative writing, it seems productive to draw once

again on language from the WAC movement. Students engaging in personal or creative writing that is explicitly framed, for instance, as a WTL experience may respond by showing explicit investment in that kind of writing as writing that may belong within a science major. At the same time, disciplinary writing framed as a WID experience that socializes students into disciplinary ways of thinking may then help students develop declarative knowledge about writing genres as responses to recurring social exigencies or needs. Educators may especially be able to leverage the reflective power of journaling as a WTL experience and the WID experience of such imaginative writing that is used in industry, such as science fiction prototyping (Nicholes, 2018, 2020), to give students chances to demonstrate how creative narratives lie within scientific-discourse boundaries. Participants in this study, as noted above, may have found value in more explicitly overlaying science writing with creative and personal writing.

The findings from this study, of course, must be considered in light of the study's limitations. This study followed a collective case-study approach that sought to explore a smaller number of voices. Additionally, it cannot claim to describe actual experiences that students had, but rather only those writing experiences students selected in discussions with me, a science-community outsider. How would students' descriptions of writing differ if they were being interviewed by a science professor, or by a graduate student in chemistry, rather than by an English-department participant? My positionality may have contributed to some of these findings, requiring further study into what kinds of writing engages and supports learning of science students.

The hope is that this article sparks further cross-disciplinary discussions about how to support students' learning about course content, learning about themselves, and learning about thinking and communicating in scientific discourse communities—while nurturing, at the same time, views of writing as individually personal, at times creative, and always socially situated.

References

Alshreif, N., & Nicholes, J. (2017). Metacognition and creative writing: Implications for L1 and L2 college writing experiences. *The Journal of Literature in Language Teaching, 6*(1), 73-88.

Atherton, E. (2016). Science fiction prototyping at work. *Computer, 49*(8), 109-111. doi:10.1109/MC.2016.229

Bergmann, L. S., & Zepernick, J. (2007). Disciplinarity and transfer: Students' perceptions of learning to write. *WPA Journal, 31*(1/2), 124-149. Retrieved from http://wpacouncil.org/archives/31n1-2/31n1-2bergmann-zepernick.pdf

Bishop, W. (1993). Writing is/and therapy?: Raising questions about writing classrooms and writing program administration. *Journal of Advanced Composition, 13*(2), 503-516.

Britton, J., Burgess, T., Martin, N., McLeod, A., & Rosen, H. (1975). *The development of writing abilities (11–18)*. London, United Kingdom: Macmillan.

Bucholtz, M. (2000). The politics of transcription. *Journal of Pragmatics, 32*(10), 1439-1465. doi:10.1016/S0378-2166(99)00094-6

Carter, M., Ferzli, M., & Wiebe, E. N. (2007). Writing to learn by learning to write in the disciplines. *Journal of Business and Technical Communication, 21*(3), 278-302.

Condon, W., & Rutz, C. (2012). A taxonomy of writing across the curriculum programs: Evolving to serve broader agendas. *College Composition and Communication, 64*(2), 357-382.

Djikic, M., Oatley, K., & Moldoveanu, M. C. (2013). Reading other minds: Effects of literature on empathy. *Scientific Study of Literature, 3*(1), 28-47. doi:10.1075/ssol.3.1.06dji

Draudt, A., Hadley, J., Hogan, R., Murray, L., Stock, G., & West, J. R. (2015). Six insights about science fiction prototyping. *Computer, 48*(5), 69-71.

Driscoll, D. L. (2011). Connected, disconnected, or uncertain: Student attitudes about future writing contexts and perceptions of transfer from first year writing to the disciplines. *Across the Disciplines: A Journal of Language, Learning, and Academic Writing, 8*(2). Retrieved from http://wac.colostate.edu/atd/articles/driscoll2011/index.cfm

Emerson, L. (2016). *The forgotten tribe: Scientists as writers*. Fort Collins, CO: The WAC Clearinghouse.

Emerson, L. (2019). “I’m not a writer”: Shaping the literacy-related attitudes and beliefs of students and teachers in STEM disciplines. In V. Prain & B. M. Hand (Eds.), *Theorizing the future of science education research: Contemporary trends and issues in science education* (pp. 169-187). Cham, Switzerland: Springer.

Fulwiler, T. (1982). The personal connection: Journal writing across the curriculum. In T. Fulwiler & A. Young (Eds.), *Language connections: Writing and reading across the curriculum* (pp. 15-32). Urbana, IL: National Council of Teachers of English.

Gillen, C. M., Kerkhoff, A. J., Lynn, D. H., McFarlane, H. G., Niemiec, A. J., Petersen, S. C., & Reach, A. D. (2020). Does creative writing improve scientific writing and learning? *The FASEB Journal, 34*(S1). doi:10.1096/fasebj.2020.34.s1.05351

Hadzigeorgiou, Y. (2016). *Imaginative science education: The central role of imagination in science education*. Cham, Switzerland: Springer.

Hadzigeorgiou, Y., & Fotinos, N. (2007). Imaginative thinking and the learning of science. *The Science Education Review, 6*(1), 15-23.

Hanauer, D. I. (2003). Multicultural moments in poetry: The importance of the unique. *The Canadian Modern Language Journal: La revue canadienne des langues vivantes, 60*(1), 69-88. doi:10.3138/cmlr.60.1.69

Henary, M., Owens, E. A., & Tawney, J. G. (2015). Creative report writing in undergraduate organic chemistry laboratory inspires nonmajors. *Journal of Chemical Education, 92*(1), 90-95. doi:10.1021/ed5002619

Iida, A. (2012). The value of poetry writing: Cross-genre literacy development in a second language. *Scientific Study of Literature, 2*(1), 60-82. doi:10.1075/ssol.2.1.04iid

Johnson, D. R. (2013). Transportation into literary fiction reduces prejudice against and increases empathy for Arab-Muslims. *Scientific Study of Literature, 3*(1), 77-92. doi:10.1075/ssol.3.1.08joh

Killingbeck, K. (2006). Field botany and creative writing: Where the science of writing meets the writing of science. *Journal of College Science Teaching, 35*(7), 26-28.

Kymalainen, T., Perala, P., Hakulinen, J., Heimonen, T., James, J., & Pera, J. (2015). Evaluating a future remote control environment with an experience-driven science fiction prototype. *2015 International Conference on Intelligent Environments (IE)*, 81-88. doi:10.1109/IE.2015.19

Martin, L. J. (2012). Scientists as writers. *Scientific American*. Retrieved from https://blogs.scientificamerican.com/guest-blog/scientists-as-writers/

McLeod, S. H. (1992/2000). Writing across the curriculum: An introduction. In S. H. McLeod & M. Soven (Eds.), *Writing across the curriculum: A guide to developing programs* (pp. 1-8). Fort Collins, CO: The WAC Clearinghouse.

Melzer, D. (2014). *Assignments across the curriculum: A national study of college writing*. Logan: Utah State University.

Nicholes, J. (2018). Developing STEM interest and genre knowledge through science fiction prototyping. *The STEAM Journal, 3*(2), 1-13.
Nicholes, J. (2020). Science fiction prototyping's features and impact on college students' perceptions of writing: An applied literariness study. *Scientific Study of Literature, 10*(1), 128-164. doi:10.1075/ssol.20002.nic
Shanahan, C. (2004). Teaching science through literacy. In T. L. Jetton & J. A. Dole (Eds.), *Adolescent literacy research and practice* (pp. 75-93). New York, NY: The Guilford Press.
Smagorinsky, P. (2008). The method section as conceptual epicenter in constructing social science research reports. *Written Communication, 25*(3), 389-411. doi:10.1177/0741088308317815
Summerby-Murray, R. (2010). Writing for immediacy: Narrative writing as a teaching technique in undergraduate cultural geography. *Journal of Geography in Higher Education, 34*(2), 231-245. doi:10.1080/03098260903274378
Swales, J. M. (1990). *Genre analysis: English in academic and research settings*. Cambridge, MA: Cambridge University Press.
Swales, J. M. (2017). The concept of discourse community: Some recent personal history. *Composition Forum, 37*. Retrieved from http://www.compositionforum.com/issue/37/swales-retrospective.php
Wynn, T., & Harris, J. (2013). Toward a STEM + arts curriculum: Creating the teacher team. *Education Digest*(5), 53.

Appendix A
Interview Protocol

1. What were your experiences like with writing in chemistry classes before majoring in chemistry at this college?
    A. What kind of writing tasks or activities—in or outside of class—did you encounter?
    B. What were your experiences with those writing tasks or activities?
2. Could you tell me about some writing experiences you have had in your chemistry major here at this college?
    A. What kind of writing tasks or activities—in or outside of class—did you encounter?
    B. What were your experiences with those writing tasks or activities?

Appendix B
Transcription Conventions

Transcription conventions are adopted mainly from Bucholtz (2000):

.	end of intonation unit; falling intonation
,	end of intonation unit; fall-rise intonation
?	end of intonation unit; rising intonation
--	self-interruption; break in the intonational unit
-	self-interruption; break in the word, sound abruptly cut off
underline	emphatic stress or increased amplitude
(.)	pause of 0.5 seconds or less
(n.n)	pause of greater than 0.5 seconds
@	laughter; each token marks one pulse
[ ]	overlap beginning and end
=	latching (no pause between speaker turns) (p. 1447)