

**Best Practices for Teaching Writing in STEM:
A Literature Survey and Case Study of
San José State University's 100W Courses in STEM Disciplines**

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Introduction

STEM Fields Provide Opportunities for Graduates

Opportunities in STEM (science, technology, engineering, and math) fields are outpacing growth in other job sectors; between 1960 and 2011, the number of employees in STEM fields grew 3.3%, twice the average annual growth rate of 1.5% for the total workforce (NSF 2014). STEM employment survived the 2007-2009 downturn better than other occupations; employment, while slow, rose slightly, while the total workforce shrank during the same time period.

Estimates of the science and engineering (S&E) workforce range from approximately 5 million to over 19 million, depending on the definition used (NSF 2014). In 2010, approximately 5.4 million college graduates were employed in S&E occupations in the US: computer and math sciences (2.4 million), engineering (1.6 million), life sciences (597,000), social sciences (518,000), and physical sciences (320,000) (NSF 2014). In addition to these specialized fields, S&E knowledge and skills are applied throughout the US economy. Over 16.5 million college-educated employees report that their job requires competency equivalent to a bachelor's degree level of technical expertise in one or more STEM fields (NSF 2014). This is significantly higher than the 5.4 million employees with formal STEM titles (NSF 2014).

NSF reports that US universities awarded nearly 550,000 bachelor's degrees in science and engineering fields in 2011, an increase of 39% since 2001 (NSF 2014). The largest number of STEM graduates were from California; its universities conferred a total of 68,228 STEM undergraduate degrees in 2011 (NSF 2014).

Background

Need for Specialized Writing Instruction for STEM Majors in Higher Education

STEM professions vary tremendously in scope and practice, as do their professional written communication needs and standards. This is reflected in the diversity of genres developed for these disciplines, and includes specific organization, language, and style, intended for specific purpose, recipients, and/or audiences (e.g., clients, professionals, journals, publications). STEM graduates must be prepared to write these academic and/or professional documents as practitioners within their specific field; these documents include

- proposals,
- grants,
- scientific journal articles (includes abstracts),
- environmental literature,
- grant writing,
- emails/memos,
- compliance documents (legal), and
- product specifications.

In contrast to highly purposed and specialized professional writing, writing in universities must also be used to evaluate proficient understanding and communication of content, synthesis of ideas, and/or ability to identify and use genre, form/style, and formatting. Although students are asked to write using a variety of formats, often designed to mimic or teach either academic or professional writing format, style, and language, some assignments are purely for assessment. Assignments typically assigned to university students include

- essays,
- research papers,
- literature reviews,
- proposals,
- abstracts,
- lab reports,
- critiques,
- emails/memos, and
- grants.

Education provided by universities preparing students for careers in STEM fields aims to provide the theory, content, and communication skills necessary for success in these fields, while also meeting both broader university and specific departmental goals and requirements. Students typically enroll in a general writing course for freshman and a departmental or genre-specific writing course as a junior. General writing classes are designed to improve grammar and syntax, language, organization, rhetoric, and information literacy, and are often taught by faculty within or affiliated with university English departments. To prepare students in STEM majors for their transition from student to practitioner, upper-division general education or specialized classes also focus on mastery of specialized theory and content, disciplinary literacy (thinking and writing like a “professional in that specific field”), and content literacy (how to understand genre-specific writing) (Ruzycki 2015). The integration of these goals necessitates specialized writing instruction to provide the student with appropriate training in specific language, writing styles, and document production.

Challenges Encountered by Faculty Teaching Writing

Although both faculty and students value writing in education, they also acknowledge that undergraduate students enter college lacking writing skills and often do not improve throughout their post-secondary education (Fallahi, Wood, and Austad 2006). This is one of many challenges faced by professors who teach general writing classes at universities.

The most common challenge faced by faculty teaching writing classes is the large time commitment needed to grade papers in contrast to other kinds of assignments (Fallahi, Wood, and Austad 2006). In addition, the range of writing abilities and experience can vary tremendously among students in a class, and in some classes, international students and/or students for which English is not a first language may need specialized support, which faculty may not have the training or comfort level to provide. Additional skills needed for writing,

including information literacy (research), have changed substantially with the developing technology, and may require collaborations with librarians or information technology faculty (Fister 1993).

Additional challenges arise from discrepancies between faculty and student expectations and/or understanding of the assignment, which can lead to disappointment in the type or quality of work turned in and the grade that is received (Nelson and Hayes 1988; Wingate, Andon, Cogo 2011; Lea and Street 1998). Students often see papers as tasks to accomplish, in which they provide information and facts to a professor who already knows about the subject; these students often report writing assignments as “boring” or “pointless” (Nelson and Hayes 1988). In fact, faculty intention for writing assignments is for students to learn and improve their writing process and analyze and interpret the information they are interacting with (Nelson and Hayes 1988). When faculty and student expectations do not align, students fail to achieve the objectives of the assignments. Students also develop low investment strategies to complete research and writing when they feel that assignments are not clear, if they procrastinate or want to spend minimal amount of time writing, or if faculty does not intervene or interact with them during the writing process (Nelson and Hayes 1988).

Lastly, students often do not read comments on papers returned at the end of the quarter/semester, and for papers returned at other times, they report not understanding instructor comments on their writing and do not seek out clarification, making future efforts less likely to be successful (Wingate, Andon, and Cogo 2011; Hounsell 1987). Over time, failure to address these discrepancies result in recurring patterns of mistakes that seem to continue with the student through their education, even into graduate school (Fallahi, Wood, Austad 2006; Gambell 1984).

Additional Issues with Teaching Writing in STEM (Special/Specific Needs of STEM Writing)

Universities’ need to help students develop a deep understanding of content and communication skills relevant to their anticipated professional field creates a unique and often complex set of student learning objectives for professors. The faculty who teach genre-specific writing must balance these competing needs within the individual classes they teach. As a result, STEM writing faculty experience all the general concerns mentioned above, and also report discipline-specific challenges.

The most common additional issues encountered by STEM faculty teaching writing include feeling uncomfortable or being unprepared to teach writing (compared to teaching STEM content), or that they do not want to give up time teaching content to teach writing (Patterson and Slinger-Friedman 2012; Fallahi, Wood, and Austad 2006). This is possibly because many faculty are skilled academic writers, but they may have limited experience in industry contexts (Conrad, et al. 2015).

Coming into discipline-specific writing courses as juniors, many students have misconceptions or little knowledge of expected structure of writing in STEM genres (Conrad, et al. 2015).

Students may not have encountered professional papers or practiced specific genre styles or used technical language in their papers, or developed disciplinary literacy, in which students read, speak, and write using habits of thinking within a core discipline (Ruzycki 2015; Wingate, Andon, and Cogo 2011; Chapman 2003; Nelson and Hayes 1988). Conventions of their STEM profession need to be learned, and students need to be prepared to provide quality written work upon graduation for the best chances of being hired (Conrad, et al. 2015).

Other challenges arise from the pedagogical differences between English writing instructors and science teachers, who often teach writing in different ways (Pytash, et al. 2016). As a result, students may not see the connections between the two subjects, or they may need to be shown the links between writing competence and comprehension of subject material, genre conventions, and applications that require clearly communicating content (Steward, et al. 2015; Pytash, et al. 2016). Students may also lack the exposure to multi-modal skills used in STEM writing, including the use of graphs, tables, drawing, maps, and photographs to convey ideas, relationships, and significance of data (Pytash, et al. 2016; Lemke 1998).

Differences Between Student and Practitioner Work

The purpose of professional communication documents is specific and focused, intended to provide information to clients and/or peers (Conrad, et al. 2015). Practitioners write for clarity and purpose, while, by necessity, students are asked to also demonstrate understanding of theory, concepts, and competence (Conrad, et al. 2015). The need for professors to facilitate content literacy and teach genre-specific (and often, remedial) writing skills, in addition to the challenges discussed above, exemplify the challenges faced by STEM writing professors. Not surprisingly, prospective employers find that new hires from universities are often more prepared technically than in writing, and, in these cases, employers report being unsatisfied with the writing preparation students receive at universities (Conrad, et al. 2015).

Conrad, et al. (2015) found that student writing differs from practitioner writing in three distinct ways.

1. **Genre organization.** Within STEM disciplines, documents produced by practitioners are fairly standardized in terms of basic organization, even across firms and states because they serve the same or similar functions or because document content and organization are based upon convention. In contrast, students have little knowledge of expected document structure within the genre. Student papers will often lack context for the project and/or document, even when assignments are modeled on practitioner genres.
2. **Sentence structure.** STEM practitioners typically write with more concision than students (e.g., one idea per sentence) because practitioners aim to provide unambiguous and quick reading for clients for a specific purpose or outcome. Students tend to write more complex and/or compound sentences with multiple ideas, often with vague or inaccurate information, confusing sentence length and use of jargon with sounding more intelligent or professional.
3. **Word Choice.** Practitioners use more precise words and phrases, especially in engineering or areas of other detailed work. Students often choose vague words that

can convey inaccurate and/or imprecise information (i.e., superlatives or absolutes) because they do not yet value concision and accuracy in their technical writing. In addition, students lack awareness between unambiguous writing and unintentional liability and other professional consequences.

Preparing students for the STEM workplace necessitates that universities help close these gaps between student and practitioner writing. Students need to be provided with the training, tools, and experience to step into entry-level positions and provide prospective employers with the skills that they seek from graduates.

Methods

I conducted research for the San José State University Writing Center, in conjunction with Writing Across the Curriculum, during the 2016-2017 academic year, during which I served as a faculty-in-residence. This research focused on providing information to support and enhance writing instruction and resources to students in STEM majors with the goal of helping them to prepare and be competitive for STEM internships and jobs upon graduation. I was interested in documenting current approaches to teaching writing and improving student outcomes within STEM majors at universities, including SJSU. I conducted a literature survey, looking at the published results of many different scales of effort, including those undertaken university-wide, within individual departments, and in individual classes. In spring 2017, I conducted a Qualtrics survey of SJSU 100W (upper-division genre-specific writing classes) instructors in STEM disciplines to document current approaches and observations within our university. (The survey consisted of nine questions, and the questionnaire is included in the appendix.) After comparing the results of the literature survey to the administered survey, I made recommendations for improving student outcomes in STEM writing programs at SJSU on several levels: university (including support services), department, and course. Support services include the Writing Center, which supports student writers, and Writing Across the Curriculum, which supports faculty who teach writing.

Results

The results of my research are broken down into a discussion of the literature survey (and further divided by scale at the university, department, and class level) and Qualtrics survey results from SJSU 100W instructors.

Literature Survey Results: Summary of Efforts to Improve Writing in STEM

University-Scale Programs

Two universities reported successful system-wide efforts to improve STEM writing: Duke University (Moskovitz 2011) and Howard College of Arts and Sciences at Samford University (Chapman 2003). Duke's program focuses on pairing students with alumni within their field, and Samford University supports and funds significant undergraduate research and writing efforts.

The Duke Reader Project. The Duke Reader Project is a collaboration between their Writing Center and Alumni Affairs (Moskovitz 2011). The program pairs a student with an alumnus that has volunteered to read one of their papers, offer advice, and talk with them about helping their writing to aim more towards a professional audience (Moskovitz 2011). The alumni who volunteer for this program are often professionals in particular fields, including STEM, and serve as the “target audience” for the paper.

Alumni Affairs provides the platform for writing instructors to advertise specific assignments available for collaboration and provides communication with alumni to inform them of volunteer opportunities. The assignment descriptions are very specific so that alumni can determine if they can contribute comfortably, and the volunteer hours are kept to four hours total per student. These four hours offer more individual attention than a faculty member can provide to every student, yet a small and discrete time investment of the alumni. Additionally, the Reader Project provides Duke alumni with a way to stay active with the university (and vice versa) and connect students with professional contacts and interactions.

Moskovitz (2011) found that students who participate in this program improve their ability to write for a particular and specialized audience, are more likely to seek input on future writing assignments, are more critical of their own writing in the future, and are left with a better sense of writing beyond the classroom. These students were also more likely to write papers earlier and express deeper understanding of the topic on which they wrote. Alumni reported wanting to spend more time interacting with students, and many continued to volunteer in the reader pool, some up to four times.

Emphasis on Student Research: Howard College of Arts and Sciences, Samford University. At Samford University’s Howard College of Arts and Sciences, STEM writing outcomes are improved by linking writing to research opportunities. Chapman (2003) reports that the college puts a heavy emphasis on undergraduate research and writing with the goal of framing the writing requirement preparation for senior research as opposed to an obstacle to overcome or an abstract application.

Within the university, writing requirements are scaffolded, meaning that the skills learned in one class are reexamined and expanded in subsequent classes. For example, all freshman take an interdisciplinary communications course (writing intensive, oral communication, research strategies, and documentation of sources), and then specific genres are taught in each department. Within both classes, basic writing skills (i.e., grammar, rhetoric, outlining, information literacy) are introduced, and then they continue to be developed in subsequent classes using more advanced skills and applications. The overall goal of all of the writing instruction is to support student research, with a goal/requirement that undergraduate students present research at an annual university-wide “Student Showcase” (Chapman 2003). Students can then present at subject-specific regional and national meetings or National Conference of Undergraduate Research (NCUR.org) (Chapman 2003).

Students gain valuable research experience, and, because they must write for a specific goal and/or outcome, have focus and purpose, and are strongly invested in clear communication. Researchers also report that students learn more and appreciate directed research where they play a significant role (Chapman 2003).

Chapman (2003) attributes the success of Samford's program to the funding that supports it. In addition to salary, the university provides separate funding for professors who teach senior seminars or directed research courses, for students who travel to NCUR, and for the production of the Student Showcase.

Department Programs

Within individual STEM departments, writing instruction can be organized to improve student outcomes across multiple upper-division courses. To accomplish this, faculty within STEM departments must work closely to create clear goals and objectives, both within individual classes and through the series of classes required for graduation within the major. These goals and objectives must be made clear to students throughout their university careers. For example, Stewart, et al. (2015) suggested that departments draft and implement operational definitions for proficiency in oral and written communication, quantitative reasoning, information literacy, and other key educational outcomes. They found that these definitions were especially helpful if integrated into grading rubrics and student learning outcomes so that students could link individual assignments/efforts to their overall educational goals.

The STEM departments that implemented successful department-wide writing programs reported working with professionals to develop curriculum that best prepares students for jobs in their fields (Conrad, et al. 2015), scaffolding skills within and between classes to provide constant and consistent student exposure to the curriculum (Stewart, et al. 2015, Chapman 2003, Monroe 2003), as well as using writing portfolios or samples from throughout a student's journey towards graduation to evaluate writing progress (Chapman 2003; Nelson and Hayes 1988).

Collaboration Among Faculty, Practitioners, and Writing Specialists. The Civil Engineering Writing Project is based at Portland State University and also includes Cal Poly Pomona, Howard University, and Lawrence Technological University (Conrad, et al. 2015). The purpose of this project is to assemble practitioners, applied linguists, and engineering faculty to examine the differences between student and practitioner writing and develop materials to address student weaknesses and assess effectiveness. After preliminary analyses, the panel created new teaching materials, which were incorporated into existing upper-division engineering courses; these materials are currently being assessed for their effectiveness.

The principles underlying the project include

- collaboration with professionals, who provide current industry contexts and needs;
- empirical analysis of writing, including the identification of differences between practitioner and student writing (e.g., organization, language, etc.);

- functional perspective on language, including the impact of word use on meaning and communication, not just stylistic concerns;
- direct instruction, wherein instructors clearly outline expectations for writing in workplace genres, including the use of specific language and grammar; and
- design and integration of new materials into existing courses, so that no new programming is needed.

The outcome of the project was the development of new course materials: free-standing units that can be incorporated into engineering classes. The materials address the principles stated above, plus an additional criterion; materials clarify student misconceptions about writing and provide numerous examples of practitioner work. The new materials include

- introductory units, which review basic writing principles covered in previous writing courses (e.g., writing is an iterative process that includes review and revision, audience and purpose shape writing) using practitioner examples;
- genre-based units, which cover the typical purpose, audience, organization, and format of specific professional document types (using explicit comparisons with student writing for contrast);
- language units, which address effective language choices in civil engineering contexts (e.g., explain which words to use and why, how to simplify and clarify language).

The units were incorporated into seven civil engineering courses, and the quantitative results of the first term of the study showed statistically significant improvements in sentence structure ($p < 0.01$), word choices ($p < 0.05$), effectiveness of rhetorical functions ($p < 0.001$), and improvement in scores ($p < 0.05$). The success of these units indicate that collaborations between STEM faculty, practitioners/professionals, and linguists/writing specialists are effective in bridging the gap between student writing and practitioner writing, and also in preparing students for professional work in their STEM field so that prospective job seekers are well-qualified and competitive.

Scaffolding. The Chemistry Department at the University of Toronto uses a coordinated approach to teaching writing across five third-year, single-semester undergraduate courses via their Writing Instruction and Training (WIT) program (Stewart, et al. 2015). WIT is a university-supported program that assists departments in designing writing programs to strengthen and improve student writing; the Chemistry Department implemented the WIT program over six years and found that student survey results indicated notable positive responses, especially as students participated in the program for longer periods of time. This published paper provided substantial detail about the design and implementation of their program.

The WIT program uses a hierarchy of both faculty and trained teaching assistants to provide students with writing feedback in third-year lab-based undergraduate classes. The program is organized so that chemistry majors take at least one of the participating courses during their upper-division coursework within the department, although most students take several WIT classes (Stewart, et al. 2015).

For the study, the program coordinator (a faculty member within the Chemistry Department) worked with faculty and the WIT director to identify components within the selected classes that could be modified to incorporate enhanced writing elements. Additional materials were drafted for students, including rubrics, writing tip sheets, and supplementary writing information. These components were incorporated into existing assignments (e.g., lab manuals), an initial investment of between 2-10 hours per course (Stewart, et al. 2015). The courses and assignments stayed relatively stable over the course of the study, so little additional time and energy were needed beyond the first effort. Approximately 90-120 students participated in the program over the six-year study.

After the writing materials were drafted, the departmental WIT Coordinator worked with the Lead Writing Teaching Assistant, who then trained the course TAs to support instruction and grading. Specific roles and responsibilities, including writing evaluation, were set for both faculty and TAs. Rubrics and sample papers were used to ensure consistent grading, and specific instruction for TA feedback on student papers was taught and practiced. The Lead Writing Teaching Assistant was available for consultation by TAs all semester and provides a course evaluation to the faculty/instructor at the end of the semester. One of the most important concepts is the focus on the specific assignment, class outcomes, and how the efforts of both faculty and TAs support the WIT program goals within the department. These efforts may necessitate the separation of content goals from writing goals.

The scaffolded skills taught to students are intended to teach professional writing abilities needed by graduates entering the work force in Chemistry: reading examples of professional writing, researching, learning construction of an academic paper or other professional paper, becoming proficient in grammar and sentence construction, and using genre-specific language. The components deemed most successful in improving student writing in STEM are

- using design elements in several courses to better communicate the department's message about writing,
- decoupling assessment of content from writing in assignments,
- offering low-stakes writing tasks that encourage iteration (turning in lab reports for comment but no grade and then revising for final submission),
- using highly structured short tasks like writing abstracts (including fixing "bad" abstracts by rewriting them and using a model to compare their revisions), and
- providing section-by-section objectives and evaluation criteria in highly structured rubrics.

Surveys of undergraduate students who participated in the WIT program within the Chemistry Department show strong feelings among students that the writing feedback provided by the WIT program was helpful (approximately 80%), would help them write better lab reports in future classes (approximately 85%), and would help them be better scientific writers after graduation (approximately 96%) (Stewart, et al. 2015). Seniors (students who completed all graduate requirements, including WIT classes) strongly agreed that the WIT program and

feedback from their TAs helped them self-evaluate and identify areas to work on their writing (92%) and improved specific writing skills within their genre/major (84%).

Student Portfolios and Writing Comparisons. Programs designed to incrementally improve STEM writing within departments can be measured by comparing baseline abilities of first-year students with graduating seniors (Chapman 2003; Nelson and Hayes 1988). These comparisons benefit departments in two specific ways: they allow evaluation of the progress students make throughout their time in the department, and they also provide a range and realistic estimate of student achievement (Chapman 2003; Nelson and Hayes 1988). When combined with strong and clear criterion for student achievement, both portfolios and writing samples can be used to quantify assessments of any assignment and/or program that is implemented after the initial baseline is established.

Individual Courses

Within an individual course, faculty can structure writing assignments to improve student writing throughout a semester and potentially achieve lasting improvements. Writing assignments can be linked/scaffolded, and/or structured to achieve specific goals and approaches, such as identifying genre specific organization or language, and include self-diagnoses of writing issues.

Improving Students' Writing Process and Teaching Self-Identification of Writing Issues.

It is important that students come to see writing as a “contextual act” instead of a discrete task that is unrelated to either the content of a class or their future goals. Research shows that improving student understanding and practice of the writing process can help make the skills needed for research and writing transferrable to their future efforts, and that learning to self-identify their writing issues can help them stop making chronic mistakes in their writing.

Nelson and Hayes (1988) found that students who use a “process log” become familiar and comfortable with the writing process quickly. In the process log, students reflect on where they are within the writing process in relation to the assignment at hand, create a plan to accomplish specific tasks, and report what progress they have made towards completing their research and/or writing. These tasks can include searching for sources, using the library, taking notes, selecting sources, organizing papers, outlining, writing, and/or formatting. In identifying the tasks and progress, students stay focused and on-task, and they work toward a self-identified/constructed writing process.

Two studies found that the approach and strategies students take to writing papers varies depending on their understanding of the purpose of the assignment, which is related to class standing (and, therefore, experience) (Nelson and Hayes 1998; Fister 1993). First-year students tended to be more “fact finding” or content-driven, while upper division students were more concerned with finding an issue or approach (“issue driven”) to guide their writing (Nelson and Hayes 1998). First-year students tended to struggle with research and writing, trying to write papers based upon the sources that they found rather than having an idea to develop. Upper-division students had improved their research and writing skills, minimizing the time searching

for sources, improving analysis of the content and context of sources, and providing support for more independent ideas within their papers. Researchers found that over time, as students moved on from a content-driven approach to a more issue-driven approach, students were able to design better papers. They chose evidence for rhetorical purposes, producing more specific supports for their ideas rather than structuring a paper around the evidence they already had, which often resulted in an unorganized or underdeveloped idea.

The amount and type of instructor intervention in writing assignments can also make a huge difference in the amount of time and effort that students put into their research and writing. Writing is a gradual process that needs “developmental feedback” (Bharuthram and McKenna 2006), and when students perceive that they are not guided through the skills they need to learn, or get minimal feedback and intervention, they procrastinate or put little effort into their research and writing assignments (Nelson and Hayes 1998). These students often label their writing assignments as “boring” or “pointless” (Nelson and Hayes 1998). In contrast, students who are provided intermediate feedback tend to start work early and focus on high-level goals for both their research and writing, and they have improved organization and idea development.

Feedback given to students is best utilized when tied to revisions or future assignments/efforts; otherwise, students tend to ignore input and repeat mistakes. Teaching students to identify their patterns of writing errors can help them in drafting future papers and in revising current ones. One professor at SJSU identifies patterns of errors in early papers, has students practice fixing their errors, and, later in the semester, asks students to list their common error patterns at the top of subsequent papers, and then identify and fix the errors themselves (Cook 2017). Students learn the grammar theory, then identification, and finally practice that helps to make lasting changes in their writing.

Grammar support software. MacMillan’s *Writer’s Help* is an online resource, reference, diagnostic, and practice program for students. At San José State University, *Writer’s Help* has been integrated into Canvas, the campus-wide learning platform, where it can be used independently or can be directly linked to STEM writing classes. This program offers diagnostic quizzes and adaptive tutorials on a number of topics, including grammar and comprehension. In theory, the diagnostics can help faculty identify common deficiencies amongst each unique set of students in their classes, which can then be integrated into class curriculum. It can also help individual students identify deficiencies and/or areas of grammar that need additional work, practice, and attention. A series of short tutorials (called “LearningCurve” in *Writer’s Help*) in those areas can be assigned to students, resulting in links to relevant grammar lessons and focused practice to remedy their mistakes.

For all of the potential of this program to help students and provide individualized help, it can be difficult to use for both students and faculty. Feedback from SJSU students and faculty that have used the program has been favorable, but unfortunately, both students and faculty commonly experience problems accessing and using this program, especially when embedded

in 100W courses. In addition, the program can be difficult to set up and use without frequent support from MacMillan.

Integrating content and writing. Many researchers have found benefit in embedding writing assignments in STEM content courses rather than teaching writing as a separate class or module within a class (Wingate, Andon, and Cogo 2011; Monroe 2003; Conrad, et al. 2015). This decreases the amount of classes that students are required to take and helps students recognize the benefit of clear and concise writing to convey their understanding of course content. When combined with reading and practicing genre-specific format, embedded writing assignments can teach or provide students with practice in writing professional-type documents.

Clarifying assignment directives and outcomes

Students perform better when they clearly understand the purpose, steps, and outcomes of research and writing (Conrad, et al. 2015). Writing instruction that directly addresses common student misconceptions about writing can help focus student efforts to complete research and writing assignments (Conrad, et al. 2015). It is especially helpful for students to be taught about the writing process in addition to scaffolding assignments to help them through the writing process; research and writing are not linear, and they require completing several tasks simultaneously or revisiting tasks (especially research) as ideas and organization develop (Fister 1993). Students who understand the writing process will better understand the relationships between individual assignments and are more likely to be able to replicate the writing process in future classes. They are also more likely to better understand and learn professional writing structure and techniques when explained in a similar context.

Genre-specific instruction and experiences

Differences between writing by STEM students and experienced practitioners are minimized as students gain knowledge and experience in writing genre-specific documents. Class materials should teach students about expectations for workplace genres, as well as techniques for choosing effective words, using proper grammar, organizing a document, and identifying conventions of particular genres (Conrad, et al. 2015; Moskovitz 2011).

Students who are led through detailed reading of practitioner writing become acquainted with genre-specific style, organization, grammar, word choices, and punctuation (as well as number of mistakes) (Conrad, et al. 2015). The benefits of the readings are enhanced if instructors help students make explicit and empirical comparisons between student versions of the genre and practitioners' use of the genre (Conrad, et al. 2015; Wingate, Andon, and Cogo 2011). In this way, academic writing can teach "real" use of language and organization, mimic professional documents, and lead students closer towards disciplinary literacy, the concept of thinking like a practitioner in the field of choice, to support core content ideas, thinking, and effective communication (Ruzycki 2015).

Instructors can also provide students with a functional perspective on language in terms of the words, grammar, and organization used in STEM writing. For instance, language can be

analyzed and taught for its impact on meaning and communication in addition to style (Conrad, et al. 2015). Ancillary materials such as handouts, wikis, etc. are also helpful resources that can provide writing instruction and/or hints to students in addition to lectures and assignments (Conrad, et al. 2015; Stewart, et al. 2015). Language that is genre-specific should be included in writing and content lessons, as well as ancillary materials. Advanced genre-specific language assignments should ask students to revise examples of “bad” writing that they can later compare to “good” examples (Stewart, et al. 2015; Conrad, et al. 2015). These efforts allow direct comparison of student to practitioner writing, closing the gap between the two.

Experiential learning supports disciplinary literacy as students are taught with the goal of providing students with professional opportunities. In genre-specific STEM writing, students can learn to use language (vocabulary) to make explicit connections between the definition of the concept and the application and improvements in the practice of the concept (Ruzycki 2015). For example, conducting research and writing with the goal of presenting or creating a poster gives students the chance to practice professional writing and presentation skills exhibited by practitioners, giving purpose and an application for their efforts (Chapman 2003). Practical experiences are more akin to writing and projects that they will later produce as practitioners for clients and colleagues.

Also along the lines of genre-specific instruction is the use of an alternative audience for a research paper other than the instructor to provide a different, and, hopefully professional, perspective and feedback (Nelson and Hayes 1988; Ruzycki 2015). Students often see their instructor as an examiner or finder of errors in form or content, so writing for anyone else, especially a professional or other audience, may improve student performance (Nelson and Hayes 1988). In addition, practitioners can provide feedback on organization, language, grammar, and other genre-specific aspects of student writing, steering them toward a more professional outcome.

Assessment strategies

Assessing the efficacy of new techniques for improving writing skills of STEM students will identify those that are working, and to what extent, as well as those that may need refining. Strategies to measure student progress are best accomplished with an assignment at the beginning of the semester to generate a baseline sample of writing at the beginning of class to assess strengths and deficits of the class. Curriculum can be tailored to the results of the baseline, addressing common mistakes in writing and grammar, and can be taught in short (15-minute) lessons throughout the semester (Fallahi, Wood, and Austad 2006). A writing sample or assignment completed at the end of the semester can be used for comparison to the baseline sample, with parameters related to lessons taught throughout the semester.

Additionally, strong, clear rubrics can be used to assess student accomplishment in writing and/or content, for individual assignments or over several drafts of an assignment (Stewart, et al. 2015; Patterson and Slinger-Friedman 2012 Fallahi, Wood, and Austad 2006). Clearly written rubrics provide clarification of the assignment’s objectives and expectations for students, thereby improving the consistency and quality of the assignments that are submitted. Rubrics

also provide feedback on specific writing skills for individual assignments, as well as functioning as a means to measure student progress over several drafts of one assignment, or several assignments. Rubrics work best when they detail specific expectations of aspects of a writing assignment that will be evaluated, along with clear weighting of each aspect in respect to a student's score. They should be provided to students with the writing prompt and used for any peer reviews and subsequent drafts, when applicable.

Revision opportunities help students to address comments, identify patterns of mistakes and deficits, and practice writing skills (Nelson and Hayes 1988; Cook 2017). Since many students do not read comments on papers, requiring revisions forces them to work through their shortcomings on a single document, hopefully developing new skills and habits. Nelson and Hayes (1988) felt that this approach works especially well when substantial comments are provided on a low-stakes assignment (an early first draft or outline) with a chance to identify problems and improve their reports before being graded. Writing a paper in a series of drafts can also be used to teach students that research and writing are concomitant activities and that problems can be circumvented in early drafts (Fister 1993; Nelson and Hayes 1988; Stewart, et al. 2015).

Peer review can be an invaluable and transferrable skill for students. It can help them develop a critical eye, expose them to different student approaches to the assignment, and provide them with feedback for revision (Gooblar 2017; Fallahi, Wood, and Austad 2006). It can also help to lighten the workload for instructors. Instructions for peer reviews must be explicit and structured so that students have to provide constructive feedback, or they may not expend the effort or stretch their current review skills (Gooblar 2017). Gooblar (2017) also requires students to ask for specific kinds of feedback in a note provided as a cover page and provides "feedback forms," a two-sided sheet with a series of questions to answer about the draft (e.g., find the thesis and restate it in their own words) designed to help their peers (as opposed to judging them).

How to decrease the amount of time for teaching and grading

Grading writing assignments takes a substantial amount of time and is the major reason that faculty decline to assign them (Patterson and Slinger-Friedman 2012). Decreasing the time and effort in writing evaluation can increase the number of writing assignments/opportunities that instructors offer their students. There are many options for decreasing grading time and effort:

- Teaching efforts can be divided between professors and teaching assistants using a hierarchical structure to teach and grade writing (Wingate, Andon, and Cogo 2011; Stewart, et al. 2015).
- Patterson and Slinger-Friedman (2012) suggest giving completion/participation grades on some writing assignments, encouraging writing but not adding much time to an instructor's workload.
- Instructors should only provide extensive written comments and suggestions on papers that are going to be revised; summary comments are sufficient for discrete or individual writing assignments and are more likely to be read by students (Fallahi, Wood, and Austad 2006).

- As stated above, using clear rubrics for grading papers substantially reduces the amount of time needed to grade individual papers (Patterson and Slinger-Friedman 2012; Stewart, et al. 2015; Fallahi, Wood, and Austad 2006).
- Also mentioned previously, the use of peer reviews and evaluations can decrease the amount of time an instructor spends providing comments and/or grading assignments by distributing the work between students and the instructor (Fallahi, Wood, and Austad 2006).
- It requires much less time to grade assignments that are highly structured, short tasks such as abstracts and short revisions of “bad” writing than it does to grade longer papers (Stewart, et al. 2015).

Survey Results

I created a Qualtrics survey for San José State University 100W instructors in STEM disciplines to get an idea of how genre-specific writing in STEM was being taught within the university (survey questions are included in the appendix). The survey consisted of 10 questions in which participants could choose as many answers as applied, including a write-in option. Questions ranged from the area of STEM in which the participant taught 100W, the types of assignments they assign, common writing problems they encounter, the teaching practices they employ, and whether or not they collaborate with other instructors in their departments. Invitations to respond to the survey were sent out to thirty-nine 100W STEM instructors, and nine responses were recorded, a 23% response rate.

Of the nine respondents, two self-reported teaching in science (25% of respondents), three in social science (e.g., anthropology, economics, psychology, sociology) (38%), one in technology (13%), and two in engineering (25%). No 100W instructors from the Math Department responded.

The most commonly assigned formal writing assignments were research proposals (88% of respondents assigned this type of assignment), followed by long research papers (8+ pages) and annotated bibliographies (75% each), and short research papers (4-7 pages), critiques or reviews, and abstracts (50% each).

The most commonly assigned informal writing assignments were journals (71%), followed by essay exam questions (57%).

Instructors assigned the following types of professional writing assignments most often: resumés or curriculum vitae (88%), job application cover letters and PowerPoint presentations (75% each), professional emails and memoranda (38% each), and agenda (25%).

Eleven student writing issues were common in the literature. At SJSU, 100W instructors in STEM disciplines self-reported encountering all eleven of these student writing issues to varying degrees (Table 2).

Table 2. Student writing issues encountered most often by STEM 100W instructors at SJSU (self-reported).

Student Error	Percent of Respondents Encountering the Error
Mechanical errors (spelling, grammar, punctuation)	88
Developing a research question and/or thesis	75
Adequately supporting ideas/arguments	75
Using vague language and/or incorrect terminology	75
Developing a clear argument	63
Lack of transitions	50
Locating and choosing appropriate sources	38
Analytical thinking	38
Organization, logical sequencing, and/or linking of ideas	38
Paragraph organization/construction	38
Appropriate citing and referencing (avoiding plagiarism)	38

Teaching practices that most respondents employ in their classes include assigning drafts of papers due for peer review (100% of respondents); providing rubrics with their assignments, requiring drafts of papers for instructor review, and providing opportunities for revision/resubmission (after reviews or grades are assigned) (88% of respondents); providing time to free-write/brainstorm about assignments in class, requiring outlines prior to drafts of papers, offering examples of professional writing (75%); and working with tutors outside of class (50%).

Writing instruction offered by 100W instructors in STEM disciplines at SJSU includes style, format, citations, and references (100% of respondents); grammar and/or syntax, paper organization/outlining, research techniques, guidance for reading peer reviewed articles (88% each); how to address the writing prompt (63%); and scaffolded assignments (50%).

Seventy-five percent of respondents collaborate with other instructors within their departments to create a consistent and cohesive writing curriculum for their majors. These respondents cite that this is accomplished through meetings and sharing documents and metrics. All respondents report collaboration with other 100W faculty; there were no reports of collaborations with instructors of other upper-division courses within their departments, although the lack of data does not definitively rule these types of collaborations out.

Six of the nine respondents offered their most successful teaching technique, assignment, or approach to writing in STEM. The responses included the following comments.

- “Assignments that build into a lit review: pre topic, topic props, outlines, drafts, final drafts, posters”
- “Clear guidance and high expectations”
- “In class peer review is essential, allowing students to get instant feedback from different perspectives. Also, allowing student to re-write assignments they did not score well on is something I endorse and encourage”
- “Language-based pedagogy with feedback that re-enforces key terms and concepts”
- “Hands-on collaborative activities”

Comparison of Literature Review to SJSU Survey results

The techniques identified in the literature survey are condensed in table format and presented by organizational level (e.g., university-wide, department-wide, and within a class) in Table 1. Because the survey was only sent to 100W instructors in STEM disciplines, some of the techniques identified in the literature survey were not specifically included in the administered survey. This does not necessarily mean that they are not employed by San José State University faculty teaching writing in STEM, only that the question was not included, or that the 100W instructor did not or was not able to provide that information.

In some cases, additional information was available that I included in the table. For instance, the College of Science has an annual Research Day, during which graduate and undergraduate students who have participated in individual research projects present their findings in a poster session. These projects were not likely conducted via 100W classes, and are therefore not represented in survey findings, but they are included in the table.

Of the seven techniques that were specifically included in the survey, SJSU 100W instructors in STEM disciplines include all seven in their classes. With only the Writing Across the Curriculum program offering support across disciplines, and no formal collaborative opportunities, these results show some adherence to current pedagogy and best practices by respondent faculty for those techniques surveyed. An additional survey designed to solicit information from several instructors from writing-intensive upper-division courses within a single department would identify answers for other categories, and would provide a more comprehensive comparison of the various approaches to teaching writing within STEM departments at SJSU and those within the literature.

Table 1. A comparison of techniques to improve student writing identified in the literature search to those employed by SJSU instructors as self-reported in March 2017 survey and via SJSU websites. Not all teaching techniques apply to 100W instructors in STEM disciplines at SJSU (e.g., university-wide and department-wide techniques), therefore not all techniques were included in the survey.

Techniques for Teaching Writing in STEM	Included in Survey (Applicable to SJSU STEM 100W Instructors)	SJSU STEM 100W Writing Instructors Report Utilizing
University-Level Techniques		
Utilize alumni association to provide access to professionals in the field	No	
Provide research opportunities for undergraduates for practical/experiential writing (i.e., "Student Showcase")	No	Yes - SJSU College of Science Research Day (optional participation)
Department-Level Techniques		
Scaffolding writing skills amongst upper division classes	No	
Use of heirarchy of faculty and TAs for teaching and grading writing	No	
Use of student portfolios and/or writing comparisons of 1st year and graduating seniors	No	
Class-Level Techniques		
Students self-identify their writing issues/shorcomings	No	
Use of a process log to learn writing process	No	
Clarify the purpose of the writing assignments	Yes	Yes
Instructors provide substantial feedback to early drafts	Yes	Yes
Multiple revisions of documents to provide a chance to respond to feedback	Yes	Yes
Use of software to learn grammar or other writing skills	No	
Integrating teaching of writing and content	No	
Read examples of professional writing	Yes	Yes
Use language-based approach	No	Yes- Instructor volunteered information
Use experiential/research based activities to teach genre-specific writing with purpose	No	Yes - SJSU College of Science Research Day (optional participation)
Write for an alternative audience (a practioner instead of instructor)	No	
Use of rubrics	Yes	Yes
Use of peer review	Yes	Yes
Work with professionals	Yes - Interview a professional	Yes

Discussion

Teaching Writing in STEM at San Jose State University

Current writing requirements at SJSU

Current writing requirements for graduation include a first-year writing class (generally a one-semester English 1A course or a one-year Stretch English class), followed by the Writing Skills Test (WST) that qualifies a student to take the 100W class (upper-division general education writing requirement) within their major. Students must pass the 100W class within or approved by their major with a “C” or higher in order to graduate.

Genre-specific writing instruction for STEM majors occurs within STEM departments, specifically in 100W courses (Table 2). Faculty teaching writing in 100W classes are often those affiliated with that STEM department, but it is not uncommon for faculty from the English Department to be recruited to teach 100W classes for STEM departments. Most STEM departments have a genre-specific 100W classes, although the College of Engineering has a general 100W that serves all Engineering majors, and Health Science and Recreation and Nutrition, Food Science, and Packaging share a 100W class.

Table 2. STEM majors at SJSU.

Anthropology	Kinesiology	Mechanical Engineering
Biological Sciences	Mathematics and Statistics	Aerospace Engineering
Chemistry	Meteorology and Climate Science	Biomedical, chemical, and materials Engineering
Computer Science	Nursing	Civil and Environmental Engineering
Environmental Studies	Nutrition, Food Science, and Packaging	Computer Engineering
Geography	Physics and astronomy	Electrical Engineering
Geology	Psychology	General Engineering
Health Science and Recreation	Technology	Industrial and Systems Engineering

Support for Writing at SJSU

There are two programs designed specifically to support writing at SJSU: Writing Across the Curriculum (WAC) provides support to faculty, and the Writing Center (WC) offers support for students.

Writing Across the Curriculum. The WAC program at SJSU supports university-wide efforts to develop 100W and writing-intensive classes by offering workshops and seminars, providing materials, supporting research, and providing a platform by and for faculty teaching writing (<http://www.sjsu.edu/wac/>). This program emphasizes the commonalities and transferability of writing practices between majors (Monroe 2003). Research has found that WAC programs are especially useful in supporting the teaching of basic and technical writing skills (Fallahi, Wood, and Austad 2006).

SJSU's WAC program is unique in that it also offers seminars that are typically associated with Writing In the Disciplines (WID) programs. WID differs from WAC in its emphasis on disciplinary differences, diversity, and heterogeneity within and between academic fields (Monroe 2003). These seminars focus on departmental-level efforts to improve writing and seek to provide faculty with support to teach genre-specific, professional writing skills to students.

The WAC program at SJSU also supports a Writing Fellows program, which, in conjunction with SJSU's Writing Center, hires and trains students to provide embedded classroom support for specific 100W courses for an entire semester (five hours per week). The Writing Fellow works with faculty to support students both in and out of the classroom, in any and all assignments and stages of writing.

The Writing Center. SJSU's Writing Center supports student success in writing by offering one-on-one tutoring, workshops tailored for and delivered to a specific class, workshops, and online resources (such as a blog, videos, handouts). Tutors can help students with prewriting, grammar, organization, formatting, and content development issues, with the intent of improving a student's overall writing skills (as opposed to providing editing services). Although some tutors are from the English Department, their goal of supporting and supplementing writing instruction for all students is reflected in their service of all departments and colleges within the university.

During the 2016/2017 academic year, the Writing Center served 1,288 clients for 3,252 tutoring sessions (2.52 sessions per client) (Hager and Walls 2017). Of the total clients/students, 24% were from the Colleges of Engineering or Science (STEM majors), with an additional 37% from the Colleges of Social Science and Applied Sciences and Arts (not all majors within these colleges are STEM majors, but the majority are). So, potentially 50-60% of all of the students served by the Writing Center are from STEM disciplines.

Recommendations

The results of the literature survey and administered survey, when compared to SJSU's current writing requirements and programs, shows some alignment with current practices. There are, however, a number of areas where additional programming may provide additional support for STEM writing and teaching within the university.

University-wide

SJSU may benefit from a program like Duke University's Reader Project, in which alumni are recruited via the Alumni Association (or a department with a strong alumni network) to work with a student on a professional writing assignment in their area of expertise. This gives alumni a way to stay connected and give back to their alma mater (and/or department) and the students an experience and connection with professionals in their field. Students are provided a chance to get direct feedback on their writing skills and style from a practitioner in their field and a feel for how their writing will need to change as they transition to a job outside of

university. Instructors will benefit from the exposure that students get to professionals, including additional feedback on their writing.

Within SJSU, specific colleges and/or departments have “Research Day” or poster presentations/sessions in which undergraduate students present their findings from individual research projects. For instance, the College of Science has one, as does the Environmental Studies Department (within the College of Social Science), and the Computer Science Department may have in the past, although I found no evidence of one being held spring 2017. Both the College of Science and Environmental Studies events are held in the spring as the academic year winds down. It would be interesting to see if students would derive any additional benefit if the undergraduate research presentation events were combined into a campus-wide event with wider implications (for scholarship money, additional research presentation opportunities, etc.). The value in tying writing activities to a purposeful outcome may provide the context and practical application to focus student writing activities throughout the year (or, even more importantly, throughout their entire university experience). The challenge of increasing the scale of undergraduate research is the cost associated with this kind of program, which may not be supported in a public system (California State University).

WAC and WC provide significant resources and support for faculty and students teaching or enrolled in writing courses at SJSU. Additional support for STEM disciplines is available via The Writing Fellows program (joint WAC/WC program) via the use of embedded tutors in specific 100W classes. Currently, there are Writing Fellows available for the following STEM disciplines: Computer Science, Engineering, and Environmental Studies. As this program grows, additional recruitment of STEM-specific tutors (that have taken and passed that department’s 100W) will provide additional in-class writing support for STEM students and instructors.

It would be interesting to study and/or quantify the benefits of WAC and WC programs at SJSU in terms of their contributions to improvements in student learning in STEM for the faculty and students who use them versus those who do not, or to look at relationships between the benefit to research, writing, and editing skills and the amount of time spent with additional instruction and/or tutoring from any source (e.g., in-class with a professor or Writing Fellow, in the Writing Center’s workshops and/or one-on-one tutoring) and/or new assignments and/or pedagogy that develop from WAC seminars.

Within STEM Departments

I am not aware of any STEM departments on campus that scaffold their writing skills over several upper-division courses, that use a hierarchical structure to provide additional teaching opportunities in writing-intensive courses (faculty and teaching assistants), or that take writing samples from first-year students and graduating seniors for comparison (the collaboration responses from STEM 100W instructors only indicated collaboration with fellow 100W instructors.) I am also curious if there are any STEM departments that require that a writing portfolio be submitted as a graduation requirement. All of these approaches could be utilized

to quantify department-wide writing assessments and utilized to analyze the outcome of any subsequent programming changes, or to draft and implement clear departmental goals and expectations for writing, including realistic writing expectations of graduating seniors. The implementation and quantitative output of a department-wide assessment system like this could inform all levels of writing programming across the university, including first-year writing classes and WAC and WC programming.

Additionally, I am curious as to whether any STEM departments work with any professionals/practitioners in their fields in regard to student writing. I know that there are a number of STEM 100W classes that require students to interview professionals in their field of interest, but am not aware of any department that has collaborated with alumni to mentor STEM writing students similar to Duke's Reader Project (Moskovitz 2011), or developed a department-wide curriculum with practitioners and linguists and writing specialists like The Civil Engineering Writing Project at Portland State University, Cal Poly Pomona, Howard University, and Lawrence Technological University (Conrad, et al. 2015). And, if no similar collaborations exist, it would be helpful to know if the resources and will are present for the development of such programs at SJSU, or within STEM departments at SJSU.

For Individual Classes

Results of the SJSU survey of 100W instructors in STEM disciplines indicate that the majority of these instructors incorporate the techniques and approaches reported in the literature, including the use of detailed rubrics, scaffolding assignments, providing clear and detailed instructions/writing prompts, employing language-based pedagogy, providing feedback on early drafts and revisions, providing examples of professional writing, and working with tutors. Individual instructors wanting additional support for teaching writing in STEM 100W classes benefit from WAC programming, including workshops such as, "Discovering eCampus Resources for Writing Instructors," "Working with Multilingual Writers," "Providing Feedback on Student Writing," and "Designing Effective Assignments and Assignment Sequences" (among others). These seminars help streamline course organization, feedback, and grading, and they create and support a collaborative network of instructors. Several STEM writing instructors have expressed interest in sharing and collaboration specific to STEM fields, and WAC may provide the structure to support these needs, both at large and as subgroup of instructors that focus on the specific needs of STEM students and faculty.

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