

Building Science-Relevant Literacy With Technical Writing in High School

Tutorial

—Feature by
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Abstract—By drawing on the in-class work of an ongoing literacy outreach project, this paper explains how well-chosen technical writing activities can earn a place in high school science courses by enabling underperforming students (including English as a second language [ESL] students) to learn science more effectively. We adapted basic research-based text-design and usability techniques into age-appropriate exercises and cases using the cognitive apprenticeship approach. This enabled high school students, aided by explicit guidelines, to build their cognitive maturity, learn how to craft good instructions and descriptions, and apply those skills to better note taking and technical talks in their science classes.

Index Terms—Cognitive apprenticeship, descriptions, English as a second language (ESL), guidelines, high school science, instructions, literacy outreach, writing instruction.

High school science classes seldom involve formal instruction in technical writing. Science teachers are busy with other curricular material, and writing **belongs** in language arts classes. This paper shows how well-chosen technical writing activities not only blend well with the content of high school science classes, but actually enhance traditional science education in high school. It also summarizes sample techniques, exercises, and technical-writing cases that have improved the science-relevant literacy of science students in classroom practice.

CONTEXT

In 1984, empirically based text usability efforts were just starting to dominate document design. The American Institutes for Research's *Guidelines for Document Design* [1] was only three years old, as was IBM's subsequently influential threefold analysis of text "ease of use" [2] (for a comparative commentary see [3]). But technical writers Fearing and Allen had already seen the relevance of this work to high school students. In *Teaching Technical Writing in the Secondary School*, they urged high school **language arts** teachers to help native English speakers improve their performance in English classes by adding technical communication to the curriculum [4]. "Unfortunately," remarked Fearing and Allen, "few students bother to learn

it and—whether for lack of knowledge or out of fear—few secondary English teachers attempt to teach this form of writing" [4, pp. 9, 11].

Today, we have 20 more years of research on both the psychology of effective text design and the linguistics of literacy and language acquisition. What we know now shows technical writing techniques to be even more relevant to underperforming **science** students, especially those learning English as a second language (ESL), because they help these students to more adequately handle the cognitive and communication challenges posed by science classes and science careers.

In 1999 in Oakland, CA, a collaborative project began to bring empirically grounded technical writing techniques into high school classrooms. The goal was to offer a new way for students to build their neglected science-relevant literacy skills. Cosponsored by the East Bay Chapter of the Society for Technical Communication and the Computation Directorate at Lawrence Livermore National Laboratory, this ongoing project adapted "authentic" professional text-design strategies into age-appropriate cases, exercises, and workshops for high school students whose weak writing skills were undermining their performance in science [5]–[7].

Primarily, this project worked jointly with students and their teachers in school classrooms. But secondarily it yielded a library of independent, sharable instructional materials that have been posted on an internet site (http://www.ebstc.org/TechLit/TL_Front.html) and reused for in-service training of science

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teachers (e.g., at the University of California's Edward Teller Education Center). The rest of this paper surveys those materials as it explains how the project integrated technical writing with high school science (and other) classes. The inability to communicate well about technology harms society, not just individual students. The approach described here is important for everyone who seeks to mitigate that harm, not just for high school teachers.

FINDING TECHNICAL WRITING'S PLACE

Time is already scarce in science class, and every minute diverted to technical writing takes time away from other important science content. This project developed and refined ways of **integrating** technical writing with science lessons so as to:

- minimize the time diversion, and
- repay the debt by enhancing or accelerating other student work on mainstream science topics or crucial science skills.

The sections below reveal that this integration approach works because “writing activities that engage science knowledge and process skills, activate relevant world knowledge, and provide real-world contexts can help to ensure that science learning is constructive rather than rote” [8, p. 1064].

From the perspective of writing topics, we pursued five very basic areas of nonfiction prose (see left column of Table I). Starting with these, students can grow in many satisfying directions.

From the perspective of classroom challenges, teaching each topic brings up a common, serious learning problem (listed in Table I, middle column). No integration of technical writing into high school

classes that ignores these problems can earn its place in the curriculum. That is why the diverse instructional moves described below all share an important pedagogic theme.

All embody the key features of “cognitive apprenticeship” as recommended by Collins, Brown, and Newman [9, pp. 453–454]:

- observation (here, of building effective text piecemeal);
- coaching (on revision and text-improvement techniques);
- “successive approximation” (editing toward more useful prose); and
- embedding “the learning of skills and knowledge in their social and functional context” so that their authentic value is clear.

In the same tradition, each suggested strategy also **externalizes** writing “processes that are usually carried out internally” so that science students can build “an explicit internal model of what might otherwise seem a confusing or random process” [9, pp. 457, 469].

The analysis below features specific cases. But it also shows how they can be generalized within the cognitive apprenticeship framework to address each corresponding problem in diverse learning situations (for underperforming high school or college students). Table I's right column suggests how this unfolds as an effective way to build science literacy.

BUILDING FROM GUIDELINES

Basic to a cognitive apprenticeship approach to helping science students write more adequately is the overt, patient, and persistent use of technical writing **guidelines**. Posters and handouts that feature explicit, one-page checklists of simple

TABLE I
FIVE PERSISTENT TECHNICAL LITERACY PROBLEMS AND HOW THIS TEACHING STRATEGY HELPS
HIGH SCHOOL SCIENCE STUDENTS OVERCOME THEM

Instructional Topic	Problem: How To...	Proposed Solution
Guidelines	Promote focused, authentic, nonfiction writing practice.	Use explicit checklists to guide student writing and prewriting.
Instructions	Work relevant cases without assuming technical background.	Use scaffolded, edited kitchen recipes.
Descriptions	Build drafting and text-design skills iteratively, in steps.	Reconstruct big descriptions analytically, from their parts and figures.
Note Taking	Enable self-help and quick practical payback from student writing.	Apply good-description techniques to improve student notes.
Technical Talks	Rescue bad talks and the time wasted hearing them.	Extend text-usability skills to include oral presentations.

technical writing techniques (see Fig. 1) provide two key psychological benefits.

First, using overt guidelines creates a reference framework for the apprentice students. As a literacy anchor, a recurring part of different lessons and activities, such guidelines acknowledge “the importance of deliberate practice and of having a ‘coach’ who provides feedback for ways of optimizing performance” when crafting science prose [10, p. 177].

Second, guidelines empower students. “Guidelines,” notes psychologist Redish, “distill research and good practice into chunks of useful advice” [11, p. 83]. In fact, experiments by Wright show that guidelines help weak performers improve in two very specific ways:

- They gain the confidence to become **active**, to personally try the checklisted techniques.

- They find and fix problems more **consistently** than those without them [12].

Both changes are vital for further skill building. Guidelines thus address the problem of getting poor writers to practice, even if the practice is brief and heavily scaffolded. Teachers can easily generalize the specific guidelines in Fig. 1 by adjusting their vocabulary or elaborateness to suit student needs.

INTRODUCING INSTRUCTIONS

Instructions are a familiar aspect of science practice (e.g., how to do a project, perform an experiment, or safely use a piece of equipment). Furthermore, instructions have a natural inner logic (embodied in the steps to do some task well) that structures and motivates them even for unsure students. So having students (armed with their guidelines) detect and

Guidelines for Writing Good Instructions

Organization

- Are the steps presented in the order in which they are performed?
- Is the first step really the first task that someone in the audience needs to do?
- Should a long or complex step be broken into smaller parts?
- Are all hidden steps made explicit?

Clarity

- Is each step written as an overt command (beginning with an action verb)?
- Are all steps easy to find and visually distinct?
 - List format?
 - Bullets or numbers needed?
- Is each step precise and complete enough to be followed?
 - Includes needed details?
 - Excludes irrelevant text?
- Are common problems covered?
 - Safety/danger warnings?
 - Troubleshooting tips?

Guidelines for Writing Good Descriptions

Organization

- **Overview:** Begin with a brief overview that reveals the object's
 - Overall framework, arrangement, or shape and
 - Purpose and function.
- **Parts:** Divide the object into parts and describe each part
 - in enough detail to use, make, or draw it, and
 - in a way that reveals its role, its relation to other parts.
- **Order:** Organize the part descriptions to help your reader in either
 - Spatial order (top to bottom, outside to inside) or
 - Priority order (most to least important) or
 - Chronological order (order of assembly or disassembly).

Content

- **Specifics:**
 - Include relevant features (such as size, shape, color, material, technical names).
 - Omit irrelevant background, confusing details, and needless words.
- **Comparison:** Compare features or parts with other things already familiar.
- **Contrast:** Contrast properties with different ones to reveal their significance.

Signals for Your Reader

- **Format:** Clarify your text.
 - Identify topics with clear, nested section headings.
 - Itemize related features with indenting and marks.
 - Integrate figures and text with labels and references.
- **Verbal cues:** Guide your reader's expectations.
 - Use parallel words and phrases for parallel ideas.
 - Use verbal links (*also, but, however*, etc.) to signal how your description fits together.

Fig. 1. Sample guidelines (checklists) to help high school students write effective instructions (left) and descriptions (right) by making the underlying techniques explicit and focused. Note that the instruction guidelines are questions and the description guidelines are commands; after practice with each set, students can be asked to edit either format into the other one.

correct flaws in sample sets of instructions puts key technical writing techniques in play quickly.

Recipes as Surrogates Participation and learning rise if instruction cases reinforce good scientific technique (e.g., regarding safety) but do not presuppose too much specialist knowledge. This makes kitchen recipes an excellent surrogate for laboratory procedures: the issues are authentic, but the threshold for working on them is low.

Students who practice finding and fixing weaknesses in (intentionally flawed) recipes encounter all the same design issues as they would meet in software documentation or industrial instructions [13]. Here, however, the context is familiar and nonthreatening (food). Recipe analysis quickly exposes students to (a) a writer's need to actively anticipate likely reader problems [14, pp. 24, 52], (b) a writer's social responsibility for noting safety pitfalls and inserting warnings, and (c) the key role of suitable terminology and units in reliable technical procedures [10, p. 241]. Iteratively turning a small essay on cranberry sauce (Fig. 2A) into usable instructions for making cranberry sauce (Fig. 2B) shows how such recipe-based exercises typically unfold. Other similar cases appear on the project internet site [15].

Instructions with Graphics Diagrams, tables, and technical art are often vital for good communication about science. Sample instruction sets, including recipes that need illustrations (e.g., how to cut a squash to stuff it) can readily reveal to science students why pictures are helpful. More importantly, such cases teach how

to critically assess draft figures, just as draft text, for usability flaws [16]. Likewise, the recipes presented in table format at the hobbyist site www.cookingforengineers.com show how text layout and astute (word) diagrams can greatly improve the clarity of a procedure.

Measuring Progress Revising flawed instructions (including recipes) also introduces students to the idea, novel for most, that text usability can be measured. Simple **word counts** let even math-challenged students participate in this discovery. For example, comparing word counts for the cranberry sauce recipe (Fig. 2) before and after editing it reveals that the revised version is only about half as long as the flawed original. While this is an unusually dramatic length change, it shows students that conciseness is a symptom of text simplicity that everyone can quantify. A few cases checked by word count help students realize that even though mere shortness is **not** a guidelines' editing goal, it often accompanies other text improvement. The virtue of nonfiction conciseness is quite appealing for those students who usually struggle to fill up sheets with useless words just to meet English-class page quotas.

The Apprenticeship Challenge Some teachers are uncomfortable trying this approach without a professional technical writer as a classroom collaborator. Bereiter has pinpointed the problem:

Explicit information about thinking in different fields is especially important in elementary and secondary school, because the teachers are not usually practitioners of the disciplines they teach [including technical communication]

(2A) How to make cranberry sauce (first version)	(2B) How to make cranberry sauce (combined version)
<p>You can make a very nice whole cranberry sauce by placing 2 cups of water in a saucepan and then stirring into the water 2 cups of sugar until the sugar itself dissolves. Next boil the water-sugar mixture for 5 minutes. Taking about 4 cups of whole, raw cranberries (which is about the same as 1 pound by weight) and washing them lets you add them to the boiled solution. If you simmer them (uncovered, very gently, without stirring) until thick, about 5 minutes, you will have cranberry sauce.</p>	<p>Place in a saucepan and stir until dissolved: 2 cups of water 2 cups of sugar</p> <p>Boil for 5 minutes</p> <p>Wash and add to the sugar water 4 cups of raw cranberries (about the same as 1 pound)</p> <p>Simmer uncovered, very gently, without stirring, until the sauce is thick, about 5 minutes</p>

Fig. 2. Typical kitchen-recipe exercise to practice designing good instructions: (a) The (intentionally) flawed original draft with scaffolding, which students learn to edit and compare with (b) improved and shorter alternative. The cooking connection motivates the edits and decreases the background knowledge needed to participate.

and so “cognitive apprenticeship” is not readily available as a way of learning to think....Some of the thinking that goes on in different fields is embodied in the tools that are used. And so learning to use those tools is also a kind of learning to think [17, p. 378].

Now guideline-guided, recipe-based cases package the mental “tools” relevant for editing instructions. They externalize the secrets to be learned and thus they enable more people to lead the desired cognitive apprenticeship. Nevertheless, even with this help, language arts teachers sometimes feel that they cannot provide enough authentic coaching because of the technical content in instructions and in similar description cases (below). Science teachers (with science backgrounds) actually have an advantage when building the nonfiction literacy skills of their students. They already know how to model good handling of scientific claims, images, and quantitative relationships. They only need to add the (foregoing) text-linguistic techniques. This turns out to be psychologically easier than going the other way.

INTRODUCING DESCRIPTIONS

Description writing is another standard part of science prose. Science and engineering reports, articles, and proposals of all kinds contain useful descriptive passages. Yet for students not personally faced with these aspects of professional practice, descriptions seem artificial and unmotivated compared with instructions.

Motivated Cases Working with common objects that have an interesting underlying technology is a good way to concretely motivate description writing techniques. Paper clips, compact disks, sticky notes, and fluorescent lights have all been used successfully in this role [18]. Describing such technically rich familiar objects, guidelines in hand, can help students to:

- bridge ordinary life with scientifically informed engineering design;
- hook easily into the history of science to add human interest; and
- once again see the value of technical illustrations in adequately explaining things to others (e.g., the vivid technical art of David Macaulay [19]).

Rebuilding Descriptions But how can those students whose basic literacy skills are too weak to allow drafting their own descriptions,

even of “motivated” cases, ever practice the text-design moves needed to gradually improve their technical writing? Linguists have discovered that such students can still practice just the same (guideline-anchored) descriptive techniques by **rebuilding** a large, complex description (e.g., of a compact disk) from its scrambled, sentence-sized pieces [20], [14]. (See Fig. 3 for a sample piece from a compact-disk description.) This verbal jigsaw-puzzle exercise lets even the weakest student look for clues in each description piece that reveal its logical role in the whole:

- What content does it add?
- How exactly does it help the reader understand?
- How does it manage reader expectations?
- What can we infer from it?

Such rebuilding practice teaches students description writing incrementally with no hint of childishness. Thus student activity here embodies the “successive approximation” to mastery needed for effective cognitive apprenticeship; it also builds the enabling cognitive skill of “example elaboration,” crucial for learning well from examples generally [21].

As with all cognitive apprenticeship, coaching plays an important role here. As students rebuild a big description from small parts (perhaps as a class activity), a science teacher’s focusing comments can reinforce student **attention** to detail and nurture their sense of **relevant** evidence.

Other description-rebuilding cases appear on the project internet site [22]. And this approach easily generalizes to descriptions in biology and chemistry, to suit any high school or community-college grade level. It thus illustrates well the promised synergy between technical writing and enhanced science education: learning how to make every word work to help a colleague, how to learn better from examples, and how to detect important details (in prose and in practice) all give students a cognitive advantage for pursuing science in class and in life.

(c) Above the reflective metal layer is a coat of acrylic lacquer that protects the metal from scratches and oxidation. It also allows printing descriptive labels safely on the top side of the disk.

Fig. 3. One piece of a long description of a compact disk (here, the third part of a list describing its layers). By attending to the rhetorical clues within each text fragment (sequencing signals, implied comparisons, pronouns), even poor writers can practice reconstructing a good description as they discover what each part contributes to the success of the whole.

IMPROVING NOTE TAKING

Science students often do not, or more disturbingly, **cannot** take adequate, useful notes. Their inability to effectively write even for themselves thus thwarts their later success on class projects, reports, and tests that require self-review of previous work.

But note taking is just a special case of writing good descriptions—for oneself. Using the incremental, guideline-anchored approach for building up competence with scientific descriptions in general (already laid out above), science teachers can build relevant note-taking skills too. The first step is to stress that taking adequate notes is not an isolated, frustration-laden classroom duty but rather a job of describing well for an audience of one. Second, students need to recognize that this is yet another text-engineering project to which their (now) familiar design techniques apply. Finally, this approach enables very focused practice: most students omit overt lists, organizing hierarchical headings and simple clarifying diagrams from their own notes, for example, but the students benefit quickly from trying these “framing effects” [23]. For many students, their motivation increases when told that these same note-improvement techniques are just the ones recommended to professional “crime scene investigators,” which makes these efforts an apprenticeship for real life (see [24, Ch. 3]).

Furthermore, inadequate note taking (in English) often undermines the science success of English language learners [25]. This is because useful science notes demand more sophisticated language skills than mere “social English” affords. Focused, technique-explicit, nonfiction writing exercises, such as those discussed above, can not only directly address this ESL note-taking problem, but the benefits also flow back into other language-constrained areas of student life. When technical writing lessons improve the formal academic English of ESL Hispanic students, for instance, those students often improve their literacy levels in Spanish too (because the same critical and analytical skills benefit text design in both languages) [26, p. 12]. In some cases, this even triggers a social “language leadership” role for the newly science-literate student, who then promotes the English skills of other family members as well [27, pp. 292–293].

AMPLIFYING TECHNICAL TALKS

Technical talks, usually end-of-project or end-of-term activity reviews presented for classmates, are common in science classes. They

pose a learning dilemma, however. On the one hand, many students giving inept talks make it hard for others to actually learn about the work done, while the presenters too often just reinforce bad presentation habits by exercising them in public. On the other hand, the literature on how to give good technical talks is huge, and trying to share it easily with students is daunting.

As with note taking, the foregoing cognitive apprenticeship approach to building technical-writing skills offers a constructive alternative. Students can handle technical talks as one more specific application (this time to **oral** information delivery) of the basic text-design and usability principles that they already met through instructions and descriptions [28]. So they can directly and visibly improve their performance (which benefits listener-learning too) without a time-consuming content detour for the coaching teacher.

Signalling content transitions, disclosing the talk’s structure, managing repetition, and integrating text and graphics to make slides truly helpful for their audience—all these moves gently extend the good-description guidelines and nicely apply empirical research on effective text design to fit oral delivery [16], [28]. Student presenters can thus incrementally build skill and confidence while their student listeners actually learn more from in-class project reports.

CONCLUSION

Because it embodies the cognitive apprenticeship approach to building writing skills, the integration of technical writing with high school science described here addresses five persistent problems in science literacy. As we surveyed the five aspects of our strategy in the sections above, these problems emerged (Table I summarizes them). The strength of this teaching strategy is that it builds science literacy by tackling these problems directly, in ways that science classes without technical writing ignore.

Evaluating Results The nonfiction analysis and writing skills that this approach fosters are just the ones emphasized on the English Language Arts half of the California High School Exit Exam (CAHSEE), an important short-term benefit in itself. All students in this project were required to take the CAHSEE, but many other factors influence student performance on this test. Also, the very high rate at which weak students leave classes (or leave school

entirely) during the last three years of high school, plus local administrative problems with CAHSEE score reporting, unfortunately have made formally evaluating this effort by using CAHSEE results almost hopeless.

In-class pre-test and post-test comparisons are the standard small-scale evaluation alternative. In chaotic urban classrooms where I have worked most often, student antagonism to tests and very low test participation rates make this unreliable as well. So personal observation and teacher feedback remain the most practical ways to assess results here, even if anecdotal.

Personal scrutiny of student work (as the exercises described above unfold) reveals:

- Visible gains in both writing quality and writing activity occur from week to week for those students who actually participate.
- Even students with minimal nonfiction skills can learn to draft adequate instructions (with illustrations-provided scaffolding), for example, after they practice with some weekly rewriting cases.
- If students have prior general language problems (such as bad spelling or flawed grammar), those problems persist but they do not prevent independently developing serious usability-improvement skills when the students edit text. (Even though the problems may persist, they do not prevent skill development.)

Students sometimes remark about such technical writing work, "This is hard." But, as their teachers readily confirm, that can really mean "This is new." The activities described here are often the first time that underperforming students have ever closely attended to the structure, relevance, and usefulness (for an audience) of what they write. Text anchored in real-world scientific work has thus covertly won their respect.

Teacher feedback has also been uniformly positive. Teachers note, for example, that this approach facilitates "differentiated learning": while some students do something simple with a recipe (find the verbs), others can do something more complex (edit for conciseness) at the same time. This is a great boon in classes with a broad literacy-skills spectrum. Likewise, the externalization aspect of cognitive apprenticeship enables teachers to flexibly layer their writing lessons: in those and only those classes where students make lists but fail to draft parallel list items, the teacher can easily detour into the why and how of parallel list structure.

Extended Relevance Spreading the benefits of this approach to technical writing in high school science classes calls for leadership by high school teachers, of course, but also by the college educators who prepare those teachers and by the committed, community-minded communication professionals who work with them. Student inability to craft effective nonfiction prose, especially about technical topics, has become a serious social problem. Garay and Bernhardt's 1998 anthology revealed the breadth of this problem by surveying the impact of unprepared college freshmen, verbally incompetent employees, and inarticulate citizens [29]. Other studies have confirmed the problem's depth: young urban adults ignore textual information resources because they do not understand text linguistics and they cannot critique or condense what they read [30, pp. 149, 159, 161].

The techniques and cases discussed here reveal one largely neglected solution strategy, bringing scaffolded technical writing and science education together in high school. This approach merits broad review not just by those who could directly execute it but by anyone who can affect that writing/science mix, whether as educator, collaborator, policy maker, mentor, or parent.

Studying technical writing does not magically solve all the communication problems that students, including ESL students, face in their high school science classes. But it does help teachers and underperforming students **confront** those problems broadly and deeply [13]. The strategies explained in this paper bring together authentic content and scaffolding technique in a mix that allows even unprepared students to move forward with their nonfiction writing skills. Hence, these technical-writing activities leave students better prepared for life after high school, whether that involves a career in science or simply more adequate participation in a technological world.

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