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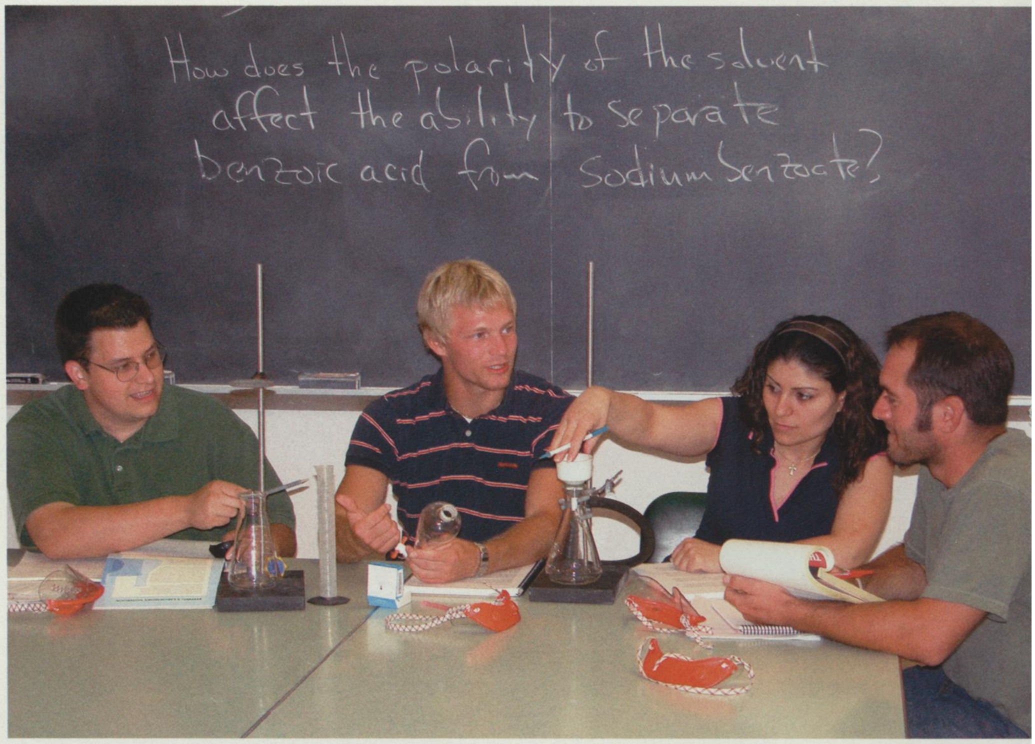
Using the Science Writing Heuristic

Training Chemistry Teaching Assistants

By K.A. Burke, Brian Hand, Jason Poock, and Thomas Greenbowe



Promoting the use of the Science Writing Heuristic (SWH) among novice teaching assistants at a large university is facilitated by a program of instructional training and mentoring. Sessions include hands-on activities with guided inquiry in tandem with elements of the SWH. These provide TAs with the opportunity to both experience and practice integrating the SWH.

The Science Writing Heuristic (SWH) approach incorporates guided-inquiry methods with write-to-learn strategies (Hand and Prain 2002). Interactive, guided-inquiry lab activities are coupled with student-centered classroom practices that include intra- and inter-group discussions. Learners negotiate meaning from experimental data and observations. Students construct concepts and ideas by making claims (drawing inferences) and supporting them with evidence from their experimental work. Focused reflection scaffolds on prior knowledge to integrate new ideas.

The process of the SWH has been incorporated into science curricula (including biology, chemistry, general science, geology, physical science, and physics) from prekindergarten and elementary grades through postsecondary levels (at two- and four-year institutions) (Hand and Keys 1999; Keys et al. 1999; Rudd, Greenbowe, and Hand 2001/2002; Rudd et al. 2001; Greenbowe and Hand 2005). Students whose instructors have productively integrated SWH activities and methods into their curriculum demonstrate a deeper understanding of the science they have learned. The more effective the instructor and the more receptive the learner, the more impact the SWH has on learning gains (Figure 1). Sufficient instructor preparation to integrate the SWH approach is critical, and we focus here on that preparation.

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Background

Graduate teaching assistants (TAs) are hired to assume some of the teaching duties in large general chemistry programs. They serve as liaisons between students enrolled in the course and the professor in charge. Being assigned to teach immediately on arrival at graduate school may be overwhelming to novice graduate students. When sending them into the classroom, we assume that they know what a TA is and how to teach, understand how the class is structured, are comfortable being placed in a position of authority, completely understand the chemistry level they are to teach, and convey enthusiasm for their material and for their task (Stacy 2003). However, most graduate students do not plan to teach once they have completed their degree program (Jones and Makinen 1991). For many, the first-year teaching assignment is nothing more than a requirement for graduation.

Virtually no TAs and few novice or veteran professors have had any formal (or informal) background in teacher training (learning theory, pedagogy, or methodology). Those with training generally received it during their TA experience. The

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model for most is a teacher-centered, lecture-oriented, knowledge-transmission paradigm (Tien, Roth, and Kampmeier 2002; Luft, Krudziel, and Turner 2003). Thus, the teacher-as-information-source is familiar to novice TAs, and that is what they believe they should be.

Trainers of TAs need to counter the paradigm of teacher-as-knowledge-provider by implementing training programs that model active-learning strategies. The program must engage novice TAs in learning experiences that allow them to encounter some of the same challenges, frustrations, and excitement that their students will (NRC 1996; McNeal 1998; Crowther 1999; Luft, Krudziel, and Turner 2003; Greenbowe and Hand 2005). The more thoroughly TAs are exposed to strategies, the more likely they are to use those same strategies. Thus, time is needed for practicing these strategies.

Because TA training sessions may partially compensate for lack of prior training in educational methods/concepts, aspects of the following should be provided:

- academic content knowledge and problem-solving skills;
- pedagogical content knowledge, methods, and skills;
- learning theory; and
- models of student-centered active-learning strategies.

Experienced graduate students should provide input as well as participate in training novice TAs.

Although TAs value the opportunity to receive some kind of training, one short "TA boot camp" cannot prepare novices for all they will encounter, especially for the variety of courses they might be assigned. An ongoing series of shorter training exercises during the semester is likely to serve the novices better than one overwhelming introductory session (Nurrenbern, Mickiewicz, and Francisco 1999; Luft, Krudziel, and Turner 2003).

Because a majority of TAs are novices, and many of the students are first-semester freshmen, all parties assume that the SWH approach is just a part of the introductory chemistry program and pragmatically assimilate its use. Teaching assistants are made aware that it generally requires about three weeks of experience for an instructor (novice or experienced) to achieve a comfort level with mentoring students in the use of the SWH. The learning curve for students varies, but the early adaptors may produce good work in three to four weeks. The TAs are aware that their efforts to understand the benefits of SWH strategies parallels their students' struggles to conduct fruitful discussions and to prepare acceptable lab reports. Usually by midterm, both TAs and students are competent and confident users of the SWH.

Training TAs

To assist novice TAs in conducting their SWH-oriented lab teaching roles, we give them several days of targeted classroom and lab training. This training has two purposes—to put the TAs in the role of student (specifically, to learn about using the SWH) and to model for them their role as TA. The TA preparation is a series of mutually supportive steps consisting of:

- learning about SWH principles in conjunction with guided inquiry/active learning;
- going to the lab to experience the process;
- completing two lab experiments facilitated by experienced TA mentors to gain adequate exposure to student-centered lab practices; and

FIGURE 1
Results of SWH studies.

In a longitudinal study over three semesters, TAs and their students were observed for more than 700 hours by two independent researchers (with an inter-rater reliability of over 0.95). Using a qualitative rubric, the TAs were ranked as being high (H), medium (M), or low (L) implementers of the SWH. Students were ranked as being H, M, or L in their acceptance of the SWH approach.

At the outset of the semester (prior to instruction/lab exercises), all students were administered the ACS California diagnostic examination. They took the ACS first-semester examination at the conclusion of the term. Their improvement scores (IS) were monitored according to the following equations:

(1) IS = lab section's gain score/lab section's potential gain score
(2) IS = (ACS first-semester exam – ACS California diagnostic exam)/(100 – ACS California diagnostic exam)

The higher both the TA and the student group were ranked, the more apparent the learning gains were (based on IS). The average IS for a high classroom dynamic (interaction between the TA and students) was 0.32, whereas the average IS for a low classroom dynamic was 0.11. The difference between the high and low classroom dynamic was 0.21. This represents a variation of one whole grade level on the students' cumulative semester results. This score was regardless of student ability level (e.g., students in the top half of the class versus the bottom half of the class).

FIGURE 2
Comparing student report formats for the SWH and traditional labs.

Standard report format	SWH student template
1. Title and purpose	1. Beginning questions—What are my questions?
2. Outline of procedure	2. Tests—What do I do?
3. Data and observations	3. Observations—What can I see?
4. Discussion	4. Claims—What can I claim?
5. Balanced equations, calculations, and graphs	5. Evidence—How do I know? Why am I making these claims?
	6. Reflections—How do my ideas compare with other ideas?
	7. How have my ideas changed?

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FIGURE 3

Solving a mystery.

Part 1: Observations, claims, and evidence.

You and your partner are private detectives who have been hired to investigate the death of the wealthy but eccentric Mr. Xavier, a man who was well known for his riches and for his reclusive nature. He avoided being around others because he was always filled with anxiety and startled easily. He also suffered from paranoia, and he would fire servants whom he had employed for a long time because he feared they were secretly plotting against him. He would also eat the same meal for dinner every night—two steaks cooked rare and two baked potatoes with sour cream.

Upon arriving at the tragic scene, you are told that the servants found Mr. Xavier dead in his home early this morning. The previous evening after the chef had prepared the usual dinner for Mr. Xavier, the servants had been dismissed early to avoid returning home during last night's terrible storm. When they returned in the morning, Mr. Xavier's body was found face down in the dining room.

Looking into the room, you start your investigation. The large window in the dining room has been shattered and appears to have been smashed open from the outside. The body exhibits laceration wounds and lies face down by the table, and there is a large red stain on the carpet that emanates from under the body. An open bottle of red wine and a partially eaten steak still remain on the table. A chair that has been tipped over is next to the body, and under the table is a knife with blood on it.

With this information, come up with a single claim and supporting evidence that explains how Mr. Xavier died.

Part 2: More observations, claims, and evidence.

Let's continue the story…

Due to his paranoid nature, Mr. Xavier always had Kurt Wagner, the butler, lock all doors to the mansion at night. However, detectives found that the back door had in fact been left open. Detectives found that the chef, Robert Drake, had been the last employee to leave that night. When questioned, Mr. Drake stated that the doors are supposed to lock behind him when he leaves. In addition, a bottle of medication for high cholesterol was discovered in the medicine cabinet. Also, the carpet in the dining room was wet.

With this additional information, come up with a single claim and supporting evidence that explains how Mr. Xavier died.

- discussing the differences between traditional and student-centered classrooms.

Through SWH training, TAs experienced in the SWH method model and mentor the process for novice TAs during a series of sessions.

The SWH explained

An experienced TA provides novice TAs with an overview of the SWH. Each component of an SWH lab report is compared and contrasted with a traditional lab report and the roles that good TAs play. Figure 2 (page 37) compares the features of the SWH student report to a traditional verification format.

One of the most important features of an SWH student report is a beginning question, which should be answerable only after carrying out an experiment. Emphasis is taken off yes-or-no or how-much-of type questions. Instead, one asks questions such as, "How does one measurable or observable quantity depend on another measurable or observable quantity?" For example, "How does reaction time depend on temperature of the reactant system?"

A second important feature of an SWH student report is that tests and observations are made during the lab activity. The tests students perform may be vaguely outlined for them or may be something they design completely themselves. The more opportunity students have to provide input on procedures they use, the more ownership they feel.

Based on their experimental observations and data, students decide what claim(s) they can make and what evidence (data/calculations) they have collected to support their claim(s). The process of making and supporting one or more claims helps students work together to negotiate meaning from what they have done and formulate and construct chemistry concepts. Students generally find this difficult, and TA guidance is useful. Using their results, students then decide how their claims compare to those of colleagues' or to what they have learned in class. They should think about how their ideas have been affected or changed by their lab work.

Mystery activity

To learn to distinguish between claims and evidence, TAs take part in a non–chemistry based mystery activity. First, they are divided into groups of three or four and then asked to read a short story outlining the scenario of a death (Figure 3, Part 1). In their groups, they are asked to suggest beginning questions and discuss them. Each group then writes a claim about the scenario on the chalkboard, along with supporting evidence. Each group reads a claim aloud and provides arguments to support the evidence offered. Other class members are encouraged to ask clarifying questions.

After each group has had a turn, the experienced TA facilitator talks with them. They may continue the activity with Figure 3, Part 2, and further dialog. Or, the moderator may proceed directly to the culminating discussion: "You have taken a position (made a claim) and defended it with supporting evidence. We have talked together as a class. If you had the opportunity, what questions would you ask the detective team investigating this case?" This results in a flurry of inquiries to clarify bits of provided evidence.

Finally, novice TAs are asked to summarize why they think they did the activity, including what they thought they learned about beginning questions, claims, evidence, and reading and reflections. This experience provides TAs with a concrete example to understand the SWH, especially for differentiating between making claims and providing evidence.

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Student-centered learning

Novice TAs must not only understand structural features of the SWH but also how to support a student-centered learning environment. They must create an ambiance in which students accept group work as beneficial to learning and feel comfortable discussing ideas with peers. Because many novice TAs have not had exposure to group work or student-centered learning environments, their training is accomplished via modeling by TAs experienced with both the SWH paradigm and student-centered classroom strategies.

During two separate lab experiments, experienced TAs model setting the stage for students' active learning, encouraging group work, and moderating group data generation, collection, and discussion. Each lab exercise illustrates different approaches novices could use for promoting active-learning strategies. One of the two experiments is discussed here in detail; students complete it to learn about integrating the SWH approach.

Saltwater experiment

TAs are provided a short descriptive paragraph and asked to determine how density of a saltwater solution is related to variables that can be experimentally manipulated. They are issued a set of equipment and bottles of solid sodium chloride and advised to propose one or more beginning questions. Experienced TAs model the TA's role in the student-centered lab by encouraging novices to talk with one another in pairs or groups to review what is meant by density. After they recall that density measures mass per unit volume, they devise an experimental strategy relating density to two experimental variables and outline on the chalkboard the experiments that could be undertaken.

This forces novice TAs (as students) to talk with one another about what variables they could manipulate to study the density of saltwater. Novice TAs are quickly able to draft a strategy for their work. At the same time, they are able to recognize the ways in which the experienced TAs guided them to generate their own strategy and pursuant procedures rather than telling them how.

TA teams generate and enter data into tables they create on the chalkboard. Experienced TAs model how to encourage students to discuss their findings, including trends, anomalies in trends, missing data, and so forth. Novice TAs suggest how they could answer their beginning questions by making claims from collected data and what part of that data constitutes their evidence. They are asked what further questions they might have and what further reading they might do to support any part of what they thought they had learned. Finally, they are encouraged to consider how their thinking has changed as a result of the process.

Novice TAs are able to understand the value of talking with one another about what they have learned rather than being told by someone else. They realize how much more meaningful the learning opportunity has been for them because they experience the entire process rather than have someone else simply tell them what to do, how to do it, or what they learned. Because they devise an experimental procedure to answer their own beginning questions, they are more motivated to find answers. They realize they have to assume primary responsibility for their own learning. The process is something they have to do themselves, not something that can be done for them.

Longitudinal mentoring

A two-day, how-to session about SWH training for TAs cannot begin to anticipate all questions, issues, and situations that could arise during a semester. Because members of the TA team have varied backgrounds, course demands, and research obligations, each approaches the teaching assignment differently and has individual mentoring needs. To facilitate the TA teaching experience, weekly staff meetings include a discussion of the upcoming experiment. An experienced mentor provides both oral and written suggestions for active engagement of students, hints about possible student difficulties or errors, and tips for grading reports.

An experienced SWH TA mentor is present in the lab during at least the beginning portion of each scheduled period. In this way, any uncertainties, awkwardness, or uneasiness can be remediated. TAs who have lab sessions later in the week are encouraged to attend and observe sessions earlier in the week (as their schedule permits) as well as talk with colleagues who have already run the lab. In this way, there is a process of continuous support among the graduate student team.

Feedback has been overwhelmingly positive. TAs realize that great care is taken to facilitate their first-semester teaching experience. Because the SWH format is new to them, TAs find the mentoring process invaluable to understanding how to promote student-centered learning environments and experiences as well as how to evaluate students' first attempts at compiling lab reports using the SWH format.

The TA's initial session with students tends to parallel TA training exercises. First, the TA reviews the SWH student template and explains it to students. Each aspect of the SWH is discussed along with the number of points that will be assigned to each part of a correctly completed lab report. From this explanation, students must be able to draft a lab report following the SWH format. A written copy of the SWH protocol and grading rubric is also provided.

Second, the TA facilitates the mystery activity, which is a good icebreaker for students. The activity is nonthreatening and does not depend on students having prior chemistry knowledge. The TA leads students through the activity from the point of view of the different parts of the SWH, from beginning questions to reading/reflections, helping students see for themselves how it all fits together. At this time, students can ask questions to clarify any misunderstandings they might have.

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Third, the TA sets up student-centered active learning. Although experimental procedures and analyses will differ from week to week, basic student-centered strategies will not. Figure 4 compares a student-centered lab to a more traditional lab environment.

For the learning activity, students are grouped in pairs (three at the most if there is an odd number). Each person should have a task on which the success of all other group members depends. Students are given the outline of a procedure and discuss it among themselves in their group to decide what beginning questions they have. The TA encourages class members to write one or more beginning questions on the chalkboard. Students should evaluate beginning questions (combining similar ideas and rewording when appropriate). They should discuss which one or ones they want to investigate. Their experimental work should revolve around their beginning question(s).

Once the questions have been developed, the TA encourages students to prepare data tables on the chalkboard. Then, students enter pertinent information. The data tables should clearly identify what variables are being studied as well as which groups are working on each part. One section of the data table should include necessary calculations.

The TA tells students to enter data in the table as soon as they have collected it. Only when all (or most) of the data have been entered can the class identify anomalies or outlying data points and begin to make meaning from information collected. The TA circulates through the classroom, engaging students by asking probing questions to determine how well they understand what they are doing and what the exercise is meant to help them to discover. If asked a question, the TA redirects the question to the group to help students learn that they have peers who are frequently able to answer their questions.

After all data have been collected, students are encouraged to determine what trend(s) can be observed. They are also encouraged to make a claim and support it with evidence. The claim usually will (but may not always) answer a beginning question. Through the course of the lab period, students' beginning questions may change. Posing claims and providing supporting evidence should help them to make meaning from experimental results. Students are then asked what other question(s) they might have for one another or the TA after completing the discussion. They should also be asked what information they could read in their text.

For the first student lab activity, students get a one-page handout to complete. They are asked to investigate how density of a saltwater solution can be related to two separate experimental variables that they must determine themselves. They are provided this goal, but no overt proce-

FIGURE 4

Comparing a traditional lab session to a student-centered lab session.

Segment of the lab class session	Traditional lab	Student-centered lab
Pre-lab	The TA gives step-by-step directions and asks for questions related to the cookbook procedure.	a. Students write beginning questions (BQs) on the chalkboard. b. Together the class discusses which BQs to investigate. c. Students talk about how to divide the tasks among groups and what data need to be collected. d. Students prepare a class data table on the chalkboard.
Students perform experimental work	Students follow the procedure outlined in the lab manual or by the TA. Students stay at their own experimental workstation and talk mainly with their partner (unless they ask the TA a question).	a. Students perform lab work necessary to answer their own questions. b. Students talk with other group members and other lab groups about what they find.
Data collection	Lab partners check with one another to be certain that both have all data, then leave.	a. Each group enters data in the class data table on the chalkboard. b. Groups who have finished their part walk around the classroom to check with other groups to determine whether any other group needs help completing their task(s) or calculations.
Discussion	Students may ask questions of their partners or the TA and then leave the classroom.	a. As soon as more than half the data have been entered in the table, students begin to look for trends to answer their BQs. If data do not agree with an apparent trend, students may repeat their work. b. When all data are on the board, students critically evaluate the information. c. Students work together to negotiate meaning, construct a concept, and answer BQs. d. Students write and discuss an appropriate claim and provide supporting evidence. e. A short discussion of topics for reflection may also occur.

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dure for how to accomplish it. They must work together to devise it.

The density of saltwater solutions exercise is a good lead-in to student-centered learning and the SWH. The concept of density is not overwhelmingly challenging. Several students in each group will recall the density relationship between mass and volume. Usual measurement units are grams (mass) and milliliters or cubic centimeters (volume). Most students are familiar with these units. They do group work, design data tables on the chalkboard, enter data in the tables, and generate discussions among themselves. Students become familiar with balances and their mass tolerances and with volumetric equipment and its ability to provide them with useful information. They must work together to generate a plan of what they want to study, but the task is not overwhelmingly challenging. With peer guidance, even those with minimal lab skills can succeed.

Progress

Given the difficulties in the willingness and abilities of the large number of TAs required for our freshman chemistry lab course, we are pleased with the impact of the SWH approach. Our data (Greenbowe and Hand 2005) show that when both TAs and students actively use the SWH approach, students make significant gains on the ACS first-semester examination, as compared to students who have experienced poor or no implementation of the method. (A brief description of the studies is provided in Figure 1, page 37.)

In addition, student composite scores in the lecture portion of the course are significantly higher for those who have experienced a high level of implementation of the SWH approach in the lab. Such results encourage us to continue refining and improving strategies to help TAs play a meaningful role in supporting chemistry student success. ■

Online resources

Visit the authors' website at *http://avogadro.chem.iastate.edu/SWH/homepage.htm* to learn more about the components of a collaborative-inquiry lab session based on SWH.

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