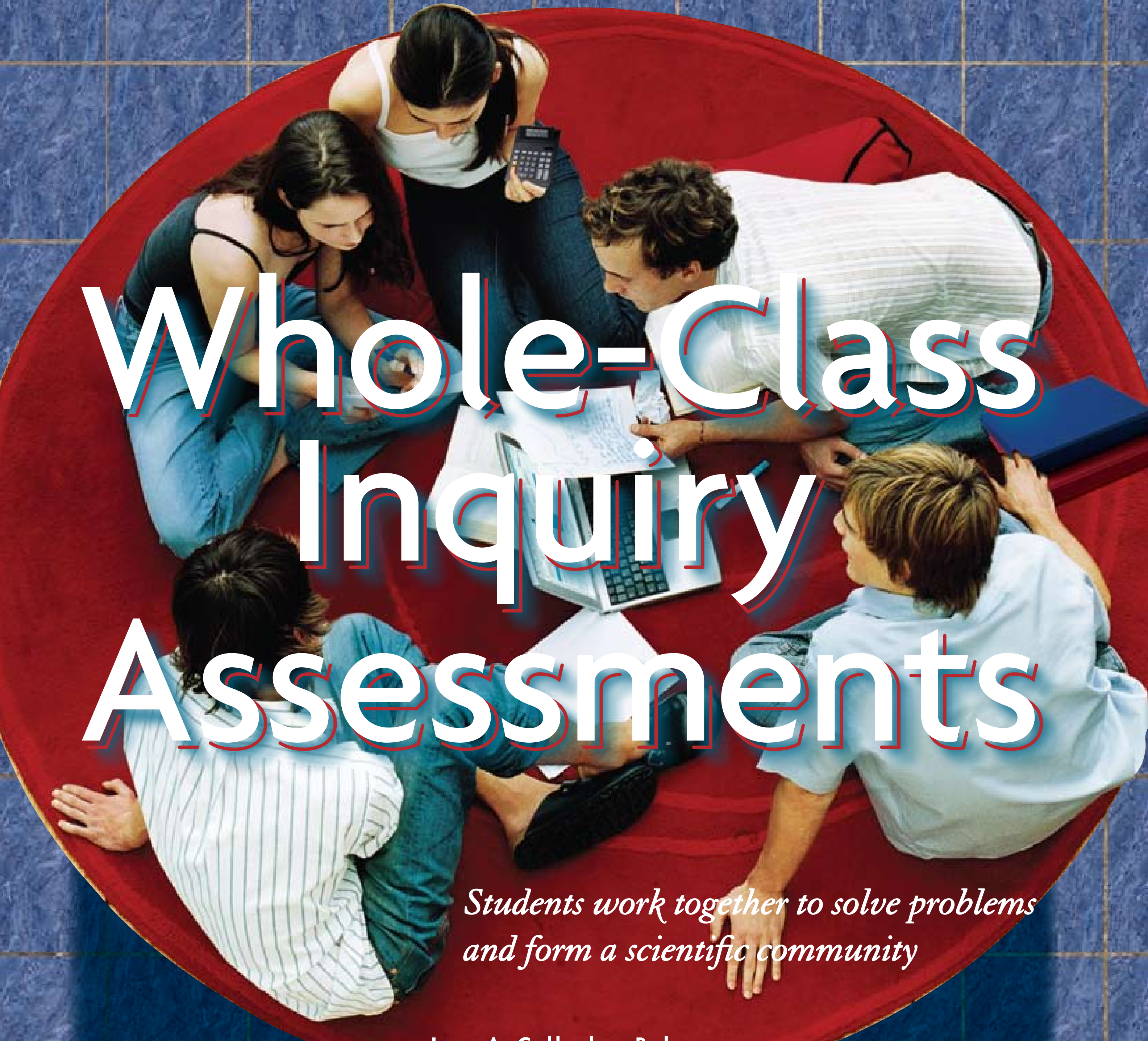


Whole-Class Inquiry Assessments

Students work together to solve problems and form a scientific community

Joan A. Gallagher-Bolos
and Dennis W. Smithenry

Like many science teachers, we feel there is a time and place for using the traditional paper-and-pencil test to assess a student's mastery of a particular topic. However, in our classrooms, we also dig deeper by including an assessment that evaluates a student's ability to work with other students and collectively apply knowledge to a problem in an authentic setting. At the end of each unit, we give students an individual paper-and-pencil test that typically lasts half of a 90-minute class session. For the remaining time, we engage them in some sort of challenge that requires the entire class to work together. We call these challenges "whole-class inquiry (WCI) assessments," which range from challenging, paper-and-pencil puzzles (Figure 1, p. 40) to lab-based problems (Figure 2, p. 41) that require students to apply their own gathered data to a new scenario; the latter might also require students to perform a lab with new parameters, or to answer a question using data from a previous lab.

The following scenario describes what typically happens during a second semester WCI assessment:

"That is it, everybody. Time is up! Quickly turn in your tests, and have a seat." It is February, and students have just completed their unit paper-and-pencil test on solutions chemistry. The teacher collects all individual tests, and then places both an overhead transparency and cover sheet (Figure 1) *on the front lab table. "Okay, now here is your class test. You are to complete these questions as a class. Good luck!"*

While the teacher walks to the back of the room, two class managers quickly stand up and head to the front. One reads the cover sheet aloud while the other puts the transparency up on the overhead projector for the whole class to see. Afterward, students remain silent for a full 60 seconds while the two managers decide on a plan of attack. At the back of the room, the teacher quietly types observations on the computer.

For the next half hour, students purposefully and efficiently work together to solve the problems written on the cover sheet. As this occurs, the teacher records what students are doing and saying while making note of feedback that could help students improve in the next whole-class assessment.

FIGURE 1

Ninth WCI assessment: Cover sheet.

This WCI assessment is used for the unit on solutions chemistry.

Directions

You may use each other, your journals, calculators, and texts as resources. I will not answer any questions or provide help, nor are you allowed to leave the room. Record your answers to the questions on this sheet, and return the overhead transparency when you are finished. Please turn this in by the end of class time, or I will not look at it.

Challenge

1. Using the following description, answer questions "a" and "b" below: Three beakers, labeled 1, 2, and 3, contain one of the following three aqueous substances: silver nitrate, potassium hydroxide, or lead (II) nitrate. In order to determine which substance is in which beaker, the following data are collected:
   - Beaker 1 and 2 mixed: stays clear, no precipitate
   - Beaker 2 and 3 mixed: turns white and cloudy
   - Beaker 1 and 3 mixed: turns brown and cloudy

   a. Which substance was in each beaker?

   b. Justify your response to question "a" with narrative explanations, net ionic equations, and particulate models.
2. Using only the equipment found on the front lab table—a calorimeter, balance, thermometer, graduated cylinder, scoopula, and calcium chloride—determine the enthalpy of solution (in J) for 80 tons (72.6 Mg) of calcium chloride.
3. A container holds a 5 g solid mixture of potassium nitrate and sodium iodide. Design a lab procedure that would allow you to determine the mass of each of the solids in the container. Record this lab procedure in enough detail that a scientist who is not in this room today could successfully implement your lab procedure and solve the problem.

At this point in the year, students have experienced a number of WCI assessments, so working efficiently and effectively as a class has become routine. In this article, we present two example WCI assessments to describe how we implement these tests and use them to build a strong sense of community in our classrooms.

Laying the groundwork

High school students are quite capable of working together as a class (with minimal teacher intervention) to tackle a well-defined problem and find a solution that is acceptable to all. Our experience has shown that students rise to the challenge presented by WCI assessments because they take ownership in the process and because they have the opportunity to become part of a scientific community.

We want to stress that WCI assessments are only one part of our entire curriculum, and that WCI investigations can be incorporated as class projects as well (Gallagher-Bolos and Smithenry 2004). For instance, during the 2005–2006 school year, I (Joan Gallagher-Bolos) incorporated 6 WCI projects and 12 WCI assessments across 85 class sessions in an alternating 90-minute block schedule (Figure 3, p. 42). WCI is an overriding theme that we begin developing on the first day of class.

To successfully implement both WCI projects and assessments throughout the school year, we have found that it takes at least two weeks to establish the kind of environment in which students feel comfortable with the idea of the whole class working together on a common challenge. During the first two weeks, while teaching introductory chemistry concepts we begin to create a sense of community by focusing on five areas: trust, physical and emotional safety, communication, journaling, and class climate (Gallagher-Bolos and Smithenry 2004; Smithenry and Bolos 1997). We also introduce a few ideas on how the class can approach planning and conducting a collective experiment, analyzing the collected data, developing explanatory models, and summarizing the results into an effective presentation. These ideas help students to begin developing the collaborative and scientific-process skills that will be needed in future student-led WCI challenges.

FIGURE 2

First WCI assessment: Cover sheet.

This WCI assessment is used at the end of the first unit and builds upon a previous lab experience, the Glass Tube Lab. In this lab, each group is first asked to take five drops of ammonia on a blue cotton swab and five drops of hydrochloric acid on a pink cotton swab, place them in either end of a glass tube at the same time, observe, and record results (i.e., a white ring forms closer to the swab with hydrochloric acid). Each group is then asked to design and carry out an experiment to test if and how a particular variable affects where the white ring forms. The following WCI assessment then allows students to collectively apply what they have learned. (**Note:** For possible solutions to this challenge, visit *www.nsta.org/high school/connections.aspx*.)

Directions

You may use only each other, your journals, texts, calculators, and any materials specified within a question as resources. I have attached an overhead of the following question for the whole class to see. Record your answers to the question on this sheet, and return the overhead transparency when you are finished. The class will be assessed on safety, accuracy, and effort made as a community in the process of solving these problems. It is assumed that everyone in the room could do this problem on his or her own once you have finished as a class. I will not answer any questions or provide help, nor are you allowed to leave the room.

I must have this sheet completed and in my hands by ______________ (according to the classroom clock). I will not grade it if you fail to meet this deadline. Place this sheet and the overhead on the front lab table. Do not remove it from class.

Challenge

Using only the materials provided on the front lab tables and those in the fume hood, perform the Glass Tube Lab and make it so that the initial precipitate forms closer to the ammonia side of the tube than the hydrochloric acid side. (**Note:** Materials include a glass tube, one pink cotton swab, one blue cotton swab, two pairs of goggles, two pairs of gloves, hydrochloric acid, and ammonia.)

a. Remember safety! Use proper methods and appropriate protective equipment, and complete the investigation inside the fume hood.
b. You have only one opportunity. The first try is your only try—so think before acting!
c. The cotton portion of the cotton swab may not be placed any further into the tube than 1 cm.
d. You may not pour either of the chemicals into the tube. The hydrochloric acid must be placed on the pink cotton swab and the ammonia must be placed on the blue cotton swab. The tube must remain horizontal on the lab surface.
e. Show me the results at the 5 minute mark (which means you need to budget your time!).
f. Write down the procedure you chose to use and why you chose it.

Class interactions

In the opening scenario, we did not go into specifics about how students approached solving the problem. As a result, you may find yourself asking: Did students split the class up to work on the problems separately, and then reconvene with enough time to share responses with one another? Did they work on all three problems together with the class managers facilitating class discussion? How did they decide to elicit responses for the sheet that was turned in? The answer to these questions lies in the collective, unique personality of the class. Each class has its shining moments, and each experiences some form of frustration. But more importantly, each class is focused on working together as a scientific community to accomplish the outlined tasks.

Regardless of the class's personality, by the second semester, students will have internalized teacher feedback. Classes typically use the general approach of having two managers facilitate class discussions as the rest of the students participate by asking questions, providing ideas, accomplishing delegated or created tasks, and recording responses in individual journals. At this point in the year, students are able to work in this manner because they have experienced a number of WCI assessments and know how to successfully respond to this type of activity. Of course, it takes a great deal of effort to get students to the level described in the second semester. At the beginning of the year, things do not always go so smoothly because students do not yet have the collaborative skills or experience needed to work together effectively. They also may not have recognized the importance of ensuring that each student participates in some way and serves as a constructive member of the classroom community.

The initial assessment: Students' first experience with WCI

When our students are given their first WCI assessment at the beginning of the year, such as the one described in the following scenario and seen in Figure 2, we observe quite a range of methods used to solve the tasks outlined.

"Time is up! I need to collect your tests." Students look up at the teacher collecting the last of the papers. They have just completed their very first paper-and-pencil unit test and look drained, yet relieved. The teacher pauses a moment, and smiles. "All right everybody. Here is your class test."

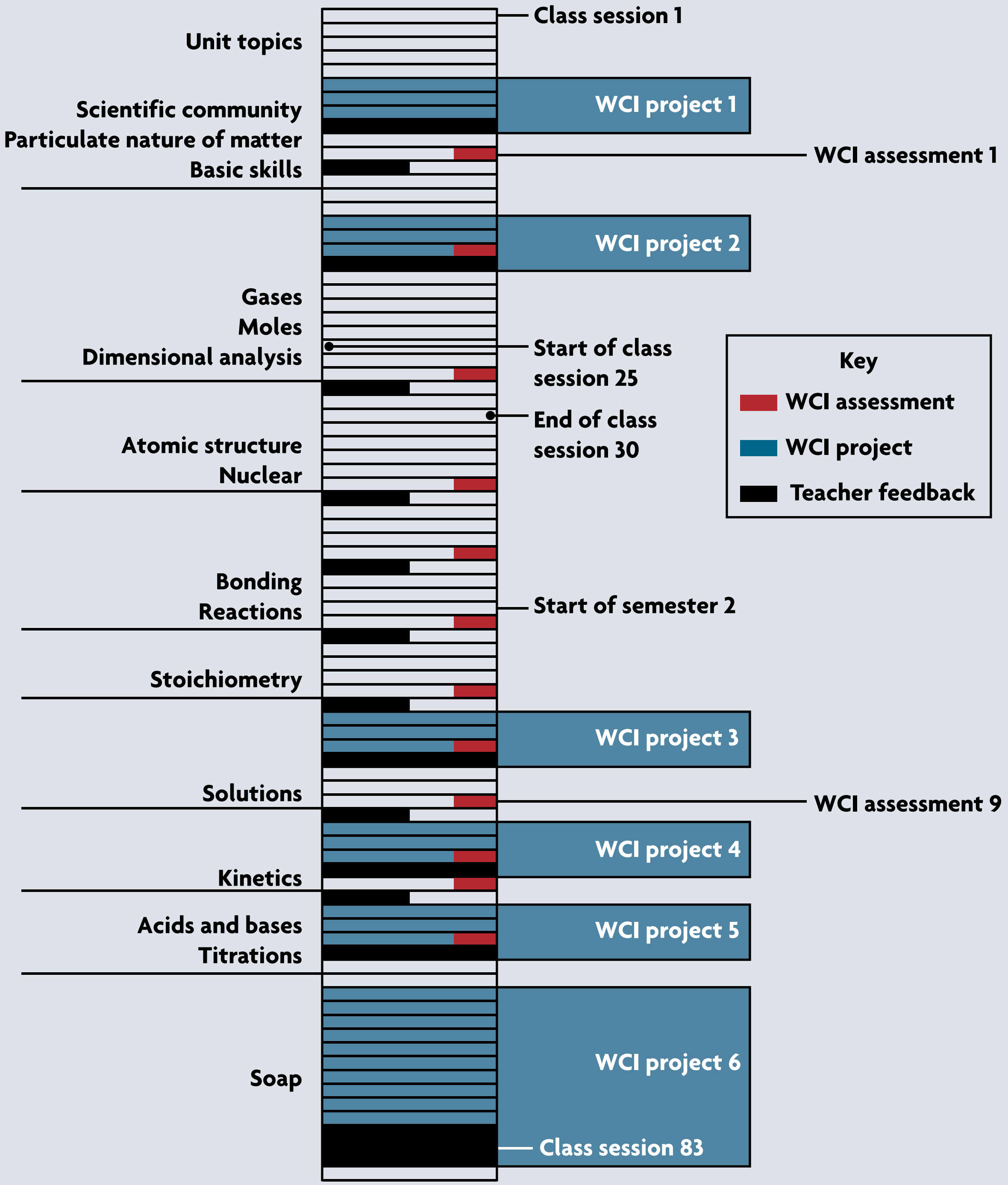
The teacher places a cover sheet and an overhead transparency on the front lab table. Students' eyes open wide. They look at one another, not knowing quite what to do. Their confusion surfaces in a flurry of questions. The teacher calmly points to the front lab table. "Go!"

Students grab the cover sheet and begin the process of answering the questions they have been assigned. The hesitancy and panic in the room are palpable. Initially, chaos and disorganization ensue, but students ultimately press on because they know they are taking a "test." The teacher quietly walks to the back of the room and starts recording observations. At the end of class, students leave feeling a bit frustrated.

FIGURE 3

Timeline of the WCI chemistry curriculum (alternating block schedule).

Six WCI projects (blue) and 12 WCI assessments (red) are incorporated throughout the year.



At times, the entire class walks to the front table and spends the allotted half-hour figuring out what to do. Other times, a handful of students takes charge and completes the activity for the rest of the students. The class's personality determines what occurs—this is because, until now, the class has only worked together on a lab, small collaborative group assignment, or team-building activity implemented during the first few weeks of class to develop trust. Working together as a class is new to them.

It is important not to give too much guidance before implementing the first WCI assessment. Students will construct a better understanding of what is required if they go through the experience with their "present" skill sets. Telling students how to do something up front does not allow the in-depth processing that takes place when students go through the experience, learn from their mistakes, evaluate feedback, and then are given a follow-up opportunity to demonstrate these gains. Regardless of what happens, this is the starting point for teacher feedback to help the class improve in future WCI projects and assessments.

Note that the WCI assessment in Figure 2 (p. 41) has more directions simply because it is the first time students have done one of these in this class, and most likely ever. During the WCI assessment, we record everything that happens: quotes, actions, conversations, mistakes, successes, and so on. We typically film this first activity to use as part of the feedback from the first WCI assessment.

We never hesitate to intervene when safety might be compromised. Since students have already been taught about proper safety procedures during the introductory two-week period, they are used to policing themselves in terms of gloves, goggles, technique, and thinking before acting. It is a rare occurrence, then, for us to have to intervene.

CAUTION

Class discussions and teacher feedback

After the first WCI assessment, we conduct a feedback session with our students. To begin, we ask them to journal their thoughts about the WCI assessment experience. Then students process their thoughts through a class discussion. Typically there are a lot of frustrations that need to be addressed; however, there are also many positive moments to relive. In addition to this class discussion, we share feedback so that students are given some direction as to how they can improve in the next WCI assessment. Each time students participate in a WCI assessment, they are given feedback on accuracy (Did they get it right?), safety (Did they use proper technique and behave safely in lab, if a lab was conducted?), and community (Did they constructively and positively work together toward accomplishing their goal?).

In terms of feedback on their community effort, one suggestion that we typically give students after their first WCI assessment is to nominate and vote on two class managers to help facilitate discussions in future WCI activities. These managers can change periodically as the year progresses. Sometimes the rotation occurs from unit to unit, quarter to quarter, or semester to semester, and there are times when the class votes to keep the original students in that position. This rotation is something teachers need to play with, but it is important to ensure that all students are given the opportunity to participate fully.

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Students' favorite part of teacher feedback tends to be the community effort piece. The visual feedback provided by video—in which students can see themselves and hear what they said during the activity—helps to develop a positive classroom climate as the year progresses. Hearing class quotes tends to pull students together in a given class: they laugh, cheer, gasp, and then move forward together.

Teacher feedback can also include individual information for specific students. Individual student personalities or characteristics will surface quickly when the teacher steps back to observe WCI assessments. In one-on-one feedback, a teacher can address concerns noticed during observation. For instance, a student who is not participating or minimally contributing to the WCI assessment might need extra help. He or she may not understand the material, may be shy, or may have come to class unprepared. Whatever the reason, because of the knowledge gained from observing the student during the WCI assessment, the teacher is better able to address the situation. A teacher may also choose to intervene by bringing up one of the previous scenarios in class, without mentioning student names, to see how the class as a whole thinks it should be handled. A teacher can also weave a correction into the next WCI assessment, such as asking specific students to record responses or present findings. However a teacher chooses to intervene, the student and the class will both grow from the experience.

Assessing WCI assessments

To put it simply, each member of the class does receive the same grade. This parallels our philosophical foundation for these WCI assessments in an "authentic setting." We all are accountable on both an individual and a community level. Academe and industry both function this way. As educators, we have chosen to incorporate both individual and community accountability into our assessment system.

Of course, each teacher must decide on his or her own assessment system. We are unaware of how assigning unique grades to students in these activities might affect the dynamic of the community's growth, but we do have evidence to support that a class grade helps to promote the community culture and that it does not hurt the individual's grade by the end of the semester. Keep in mind that a class assessment would never be worth as much as an individual test in terms of points. Also, students are not expected to be as adept at working together at the beginning of the year as they are at the end of the year, having had a year of feedback and practice, and students' grades should reflect this.

The WCI grade is determined by the class's accuracy, safety, and community effort, so the grade reflects much more than just "getting the right answer." These three components are weighted equally, and students should understand that working together as a class requires all three areas to be equally important. For instance, a class assessment may be worth 9 points at the beginning of the year, with each of the three areas receiving 3 possible points; as the year progresses and challenges become more complex, the total point value may be increased to the value of a quiz grade, which can be up to 30 points.

Peer evaluations are also possible and individual quizzes can be given after a class assessment to see who was participating and to provide for individual student accountability. This is an area that we play with and modify depending on the class and the time of year.

Student outcomes

Perhaps the most important direction for teachers in the WCI assessment is this: "I will not answer any questions or provide any help." Forcing students to think for themselves and rely on one another stretches their thinking and gives them authentic experiences as scientists. There is no one with "the answers" in scientific research. Developing and implementing a strategy for solving a problem as a community of thinkers is a very important process of science that students have the opportunity to experience in this kind of assessment.

Not only does a WCI assessment allow students to immerse themselves in a half-hour of true scientific thinking, it also reinforces other important aspects of the classroom. Each problem is intentionally designed to be more challenging than the last, and each is demanding enough to require the entire class to participate. Students begin to feel the value of their presence and participation and believe that their WCI experiences lead to the development of a set of collaborative skills (e.g., listening well, communicating effectively, being a team player) that will be useful in the future (Smithenry, Gallagher-Bolos, and Kosnik 2007). Whether a student's role is to formulate questions, offer suggestions, edit work, solve problems, or explain models, as the class progresses each student knows that sitting idly by will not help and may, at times, hurt the class's experience and outcome.

In addition, the time constraint imposed by WCI assessments helps to develop a more efficient classroom environment. Students feel a sense of pressure to get a large amount of work done in a small amount of time. They are forced to think on their feet and make sense of their decisions so as to convince a classroom of their peers that one particular plan of attack is better than another. This is one of the most difficult, and yet most valuable, lessons students receive.

Perhaps most importantly, WCI assessments teach students a bit about who they are and what they have to offer. Through this activity, students further develop their strengths and recognize their weaknesses in areas beyond science. They also develop a close-knit community and tend to feel a sincere sense of camaraderie with the people in their class. Below are some of the common responses we receive when we ask students for feedback on their experience in our classrooms at the end of the school year:

- "I have a new definition of chemistry now that I have gone through this class. Not only did I learn a lot of chemistry facts from the book and from notes, but I know how to use them just like scientists do. And I have fellow scientists to help me."
- "I learned more than just chemistry. I learned about who I am and what I have to offer."
- "This was the greatest class I have ever been in. I felt like I had something to offer. And not only that, if I kept quiet, I would actively be hurting my classmates (friends)."
- "You are sneaky, Ms. G. You got us talking about chemistry for weeks at a time without your help. And it was fun. How did you do that?"

Conclusion

When we turn the typical classroom structure upside down, we observe a dramatic increase in the amount of student-to-student dialogue and interaction as they take charge of classroom mechanics and processes. We find that our students appreciate having the opportunity to decide when to hold a class discussion, when to break into groups, when to go into the lab and collect data, and when to reconvene. Students take ownership of the project as they devise their own problem-solving strategy and decide who does what. They are capable of and interested in accepting the responsibility for dealing with the social and technical issues that normally develop in the process of working together as a community.

Overall, we feel that WCI assessments allow students to genuinely engage in the processes of science as they participate in the development of a self-sufficient, student-led scientific community. ■

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