# The Great Wakonse Earthquake of 2003: A Short, Problem-Based Introduction to the Titration Concept

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In 1995, we suggested a general blueprint for collaborative learning activities *(1).* The following principles were outlined:

- **Make problems comprehensible.** If student learning is to be subject-centered and based on prior experience, then the tasks must be comprehensible to the novice rather than simply following directions.
- **Embrace imperfection and promote improvement.** Students should not be expected to master an unfamiliar activity the first time that they do it nor be threatened with the disincentive of a grading penalty if it is not done correctly.
- **Use techniques as tools to solve problems.** We see no purpose in any discussion of "cookbook versus discovery", because it is a false dichotomy. Chemists generally begin with known procedures and strategies (cookbook) and apply them to make discoveries.
- **Integrate quantitative and qualitative tasks.** Measuring a quantity should be accompanied by the descriptive understanding that allows a student to make meaning from it by providing the context in which to evaluate the data.
- **Promote collaborative laboratory work.** Most professional careers require workers with individual responsibilities to carry them out; subsequently workers must communicate results and understand others' results, often in multidisciplinary settings.

These activities are now being incorporated into instructional materials, such as "Identification of a white solid" in Mohrig and coauthors' organic laboratory text *(2).* In ref *2,* we described how our collaborative identification question, "Who has the same substance that I have?" could be used broadly; for example, "Who has a solution with the same concentration?" In this example involving solution concentration, a principled understanding of what titration is and how it works are implicit. This is not a foregone conclusion with new learners *(3).* In this article, we would like to report "The Great Wakonse Earthquake of 2003!" as a classroom activity modeled on these instructional design principles, and which we created to introduce the titration concept[1] to new learners. The Great Earthquake incorporates collaborative learning *(4, 5)* to create a core problem *(6)* in relative identification that is at the same time a simple, honest inquiry and a vehicle for developing technical and communication skills.

## The Great Wakonse Earthquake of 2003

In May 2003, we were invited to present on the topic of "models of teaching in a science classroom" at the annual Wakonse Conference on College Teaching *(7).* In response,

> *Part 1:* The floors of the Upper Tipi begin to shake. The windows rattle. Everything outside begins to vibrate. You feel the ground tremble. Oh my goodness—either Bill Bondeson has started jogging or it is an earthquake! You head outside or towards a safe doorway.
>
> Once the earthquake ends, everyone joins together to take stock of any damage. Fortunately, no one was hurt and there was only minor damage to the buildings. Unfortunately, tectonic shifts have sunk most of Stony Creek under water and cut off access to the rest of the state. And to make matters worse, it appears that the water supply was probably contaminated. You have a few bottles of water, but certainly not enough to provide for all of the people at the conference (never mind the soon-to-be-thirsty residents of Stony Creek.)
>
> Water samples are collected from six sources (A–F).
>
> **Q1: Working together in teams of two, propose how you can determine if the water is safe to drink.**

Figure 1. Setting the scene.

> *Part 2:* A Californian, who has more experience with earthquakes, recalls seeing a page in the phone book with information that might be useful to you. He happens to have carried the page because he is going to do some backpacking on the way home and is concerned about running out of potable water. (A copy of that page appears as Figure 3).
>
> **Q2: Based on the directions from the phone book, with your partner propose how you are going to determine if the water is safe. Did your proposal change based on the new information you just received?**
>
> *Note:* You should smell the samples by wafting the air towards your nose rather than sticking your nose into the bottles and inhaling vigorously. Your nose may build up a tolerance to the smell of bleach. Additionally, excess inhalation of bleach can lead to a headache. If you can't smell any bleach on one or two tries, it is safest to assume that the sample is contaminated.
>
> *Caution:* Bleach is corrosive. If it comes in contact with your skin, wash immediately with lots of water. Bleach will also, well, bleach your clothes if it comes in contact with them.
>
> *Caution:* None of the water samples should be consumed. While the contaminated water is only being simulated, it is still not potable.

Figure 2. Providing some information.

we decided to model a teaching activity based on our collaborative identification scheme. Thus, the faculty members and graduate students attending the conference became our students, and we led them in a collaborative-learning exercise we called "The Great Wakonse Earthquake, 2003." The earthquake was a fictitious scenario introduced as the motive for the participants to study suspect drinking water and (as described below) follows from instructions that California residents have in their phone books.

### Instructional Materials

Our Wakonse audience was a mixture of about 30 faculty members and graduate students who were attending the conference. We distributed the first handout (Figure 1), which describes the scenario and poses the first problem: how can you determine whether water samples are safe to drink? We have generally allowed 2–4 minutes for this discussion, which can first be done in smaller groups and then brought out to the class as a whole. Boiling water—just to be safe—is usually suggested (although it does not answer the question, could be hard to do without power, and does not do much good on the scale of a water supply). There are often experienced campers in the room, so they may know about adding tablets of iodine and purifying filters such as those by Katadyn or SweetWater (all suggestions which, in fact, do not answer the question).

The next handout (Figure 2) includes a copy of a page from the California phone book (Figure 3). In the section titled "Disinfection of Water", there is a remarkably concise description of a titration of bacterial contamination (although it is not called titration): if you add bleach to water and the smell persists, it is likely to be free of bacteria; if the bleach smell does not persist, add more until it does. In our experience, faculty from many different disciplines grasped immediately that these instructions could be used to answer the posed question. For example, they engaged in a conversation immediately about how they could apply this technique to the qualitative concept of how one would differentiate between different degrees of water contamination; that is, the titration concept: the relationship between the quantities of the known and unknown materials.

For the last part (Figure 4), participants (in groups of 2) received differently coded samples and some instruction about the value of blind testing in science. In this setting, we observed that the immediacy of the driving question (committing to the recommendation: *Is the water safe to drink?*) made this task meaningful, as though the participants understood that they could really be in this situation. As in our other collaborative identification activities *(1),* students need to decide how to pool and share their observations and, invariably, wrestle with uncertain or contradictory information. Once the participants made their commitment to "contaminated" or "uncontaminated" and the samples have been clustered, the coding scheme was revealed. Is the group willing to commit to recommending that the water is safe to drink if, say, one of the teams testing a sample from lot A is contaminated while the other 5 teams who tested a sample from lot A say it is uncontaminated? What if it is 2:4? What if it goes the other way around, with 1 of 6 who say the lot is uncontaminated? These are all excellent departure points for discussion about sampling, reproducibility, and sources of

First Aid and Survival Guide

**h**. Check that each telephone is on its receiver. Phones that are off-hook tie up the telephone network.

**i**. Wear sturdy shoes and gloves to avoid injury from broken glass and debris.

**j**. If damage is extensive, wear a dust mask, wet handkerchief, or other cover for the nose and mouth.

**4**. Check your food and water supplies.
- **a**. DO NOT eat or drink anything from open containers near shattered glass.
- **b**. If power is off, plan meals to use up foods that will spoil quickly, or frozen foods.
- **c**. Use barbecues or camp stoves outdoors for emergency cooking.
- **d**. If water is off, you can use supplies from water heaters, toilet tanks, melted ice cubes, canned vegetables. Due to its chemical content, swimming pool or spa water should not be used as a primary source of drinking water.

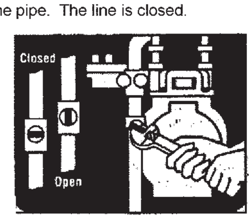
**How to Shut Off Gas Supply**

**(Do so ONLY if you notice structural damage to your hours or if you smell or hear leaking gas)**

**1**. The main shut-off valve is located next to your meter on the inlet pipe.'

**2**. Use a crescent wrench and give the valve a quarter turn in either direction.

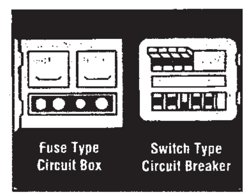
The valve will now run crosswise on the pipe. The line is closed.




**DO NOT: Turn on the gas again; let the gas company do this.**

**How to Shut off Electricity**

**1**. Look closely at your circuit breaker box or fuse-type box.




**2**. Be certain that you can turn off the electricity in an emergency.

**Disinfection of Water**

**1**. Before attempting disinfection, first strain water through a clean cloth or handkerchief to remove any sediment, floating matter or glass.

**2**. Water may be disinfected with 5.25% sodium hypochlorite solution (household chlorine bleach.) DO **NOT** use solutions in which there are active ingredients other than hypochlorite. Use the following proportions:

| | |
|---|---|
| **Clear Water** | |
| One Quart | 2 drops |
| One Gallon | 8 drops |
| 5 Gallons | ½ teaspoon |
| **Cloudy Water** | |
| One Quart | 4 drops |
| One Gallon | 16 drops |
| 5 Gallons | 1 teaspoon |

**3**. Mix water and hypochlorite thoroughly by stirring or shaking in a container. Let stand for 30 minutes before using. A slight chlorine odor should be detectable in the water. If not, repeat the dosage and let stand for an additional 15 minutes.

**Note:**
Water may also be purified by bringing it to a rapid boil. However, due to its chemical content, swimming pool or spa

Figure 3. Part of a page from a California telephone book.

*Part 3:* The residents of Stony Creek need our help, and they feel fortunate to have a bunch of smart academicians around for the Wakonse meeting. We need to be confident in your recommendation about which (if any) of the water supplies is safe. Working in your two-person group, you receive two samples from among the six water supplies. There are multiple samples from each supply spread among the teams, but you do not know which sample is from which supply (that way, we can get multiple, independent evaluations of the water through "blind testing"). The samples are coded for later comparison.

*Directions:* Test the ~100 mL (~4 oz, 1/2 cup) water sample.

Note: the bleach has been diluted in proportion to the sample size (1/2 cup is 1/8 of a quart, the volume listed in the phone book), so you can still add 2 drops of the bleach solution to do the test. Mix the bleach (thoroughly and carefully) with your water sample and let it sit for about a minute before testing.

**Q3: When you have tested your samples, which one(s) would you identify as contaminated? The entire group needs to think of a way to gather the information and report it.**

*Part 4: Further questions:*

**Q4: Does a positive result mean that you can drink any uncontaminated samples without treating them? Why or why not?**

**Q5: How could one determine if there was a difference in the level of contamination between the samples?**

**Q6: What are the limits of using this method to detect contamination?**

Figure 4. Making evaluations.

error. Interestingly, multidisciplinary faculty groups have wanted to know a bit more about titration, so we made a specific handout that includes a list of reasons why titration in a popular technique and some specific examples and applications of its use (see the Supplemental Material[W]).

In the Great Earthquake, we might have next passed out an unlabeled sample of water to everyone, saying that there were four different levels of contamination in the sample. Your task is to determine who else has the same water that you do.

## Hazards

While bleach is a common household chemical, it is corrosive. Safety goggles and gloves are recommended. If it comes in contact with skin, wash immediately with lots of water. Do not directly inhale bleach; use in a well-ventilated area. In order to detect an excess of bleach in a sample use the wafting technique; place your nose about six inches away from the sample and use you hand to draw any vapors towards you. Bleach will also bleach your clothes if it comes in contact with them. None of the water samples should be consumed. While the contaminated water is only being simulated, it is still not potable. Dispose of samples and excess bleach properly (do not mix with acids or ammonia).

## Materials

In this report, we used the Great Earthquake to provide students and faculty with an introduction to the concept of titration. Using qualitative, sense-based differences might represent a general principle for introducing the titration concept and warrants further investigation based on our experiences. For instance, in some previous unpublished work with a summer program for teachers, we adapted the easily measured, concentration-based difference in heat release from mixing aliquots of chloroform with different concentrations of bleach *(8)* as a crude thermometric titration *(9).* Although we are reporting this for the an audience of college teachers, we are confident that others will be able to adapt the activity to college and precollege students.[2]

Clearly, the scenario (Figure 1) can be rewritten for any disaster. For example, a few months after our Wakonse presentation, Ann Arbor found itself in the Great Blackout of 2003, and water quality was an authentic concern; see the Supplemental Material[W]).

We recommend the following supplies for a group of 30 students working in pairs:

- 1–1.5 L tap (not deionized[3]) water (the "uncontaminated" water)
- 2–3 L ($4 \times 10^{-4}$ M) sodium thiosulfate (the "bacterially contaminated" water)
- 30 coded sample containers (plastic bottles) representing the six fictitious sampling locations
- 150-mL chlorine bleach (commercial brands of 6% hypochlorite, unscented) diluted 1 part bleach to 7 parts water (A fresh bottle of bleach works best.)
- 15 small, capped containers and polypipets for dispensing bleach
- Separate handouts (see Figures 1–4) to pass out sequentially

In our scenario, we identified six sample sites (A–F), from which 4–6 samples have been taken. In order to maximize the impact of the group work, including individual responsibility within the group, and to make the point about multiple, blind testing, all 30 of the "samples" are given a different sample identification code. (See the Supplemental Material[W] for actual coding.) We added 100 mL of uncontaminated water to the containers from two of the sites (C, E) and 100 mL of contaminated water to the containers from the other four sites (A, B, D, F). We also dispensed about 5 mL of diluted bleach to each of 15 small, capped containers. The ($4 \times 10^{-4}$ M) sodium thiosulfate solution did not smell of bleach even when 30 drops of diluted bleach were added.

## Additional Chemistry

Other chemical concepts such as oxidation–reduction and equilibrium can be included in adaptation of this activity. For example, chlorine bleach (sodium hypochlorite solution) is most commonly made by bubbling chlorine gas through sodium hydroxide:

$$Cl_2 + 2NaOH \rightleftharpoons NaOCl + NaCl + H_2O \quad \Delta H < 0 \quad (1)$$

The characteristic smell of bleach comes from the chlorine gas that is produced by the solution as it equilibrates. UV light breaks down chlorine; this is why bleach bottles are not transparent.

In contaminated water samples, the hypochlorite of bleach is used to kill (oxidize) bacteria. This is not a chlorine forming process, so there is no "chlorine smell". In the case of sodium thiosulfate contaminated water, a redox reaction occurs between hypochlorite and thiosulfate (eqs 2 and 3),

$$H_2O + ClO^- + 2e^- \rightarrow Cl^- + 2OH^- \quad (2)$$

$$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^- \quad (3)$$

which produces chloride ion rather than chlorine. The equilibrium in eq 1 is shifted towards the products resulting in no chlorine smell. In fact sodium thiosulfate is used to reduce the level of chlorine of overchlorinated pools.

Other sources of information on the use of chlorine for disinfection of water include the EPA, the Chlorine Chemistry Council, and two articles in previous issues of this *Journal (10, 11).* Those interested in the history of chlorine would find the three articles by Baldwin in early issues of this *Journal* of interest *(12–14).*

## W Supplemental Material

Handouts for the students, notes on titration, the coding scheme, and modifications for a power blackout are available in this issue of *JCE Online*.

## Notes

1. For the purposes of this article, we are using the term "titration concept" as an understanding of what it means to combine different chemical species and make a conclusion about the equivalency of an underlying idea—concentration—on the basis of a macroscopic effect—odor.

2. As one of our reviewers emphasized, comparing the results obtained from these more qualitative titrations with a more traditional quantitative procedure done subsequently on the same system will greatly enrich the activity of both, presumably by making more comprehensible the refinement of a question ("how much, exactly?") after addressing the original question ("how much, approximately?").

3. This equilibrium is present in bleach:

$$Cl_2 + 2NaOH \rightleftharpoons NaOCl + NaCl + H_2O + \text{heat}$$

The use of deionized water lacking chloride ion results in a shift of the equilibrium towards the products and will thus not produce the chlorine at a level detectable by the nose and thus the water appears contaminated.

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