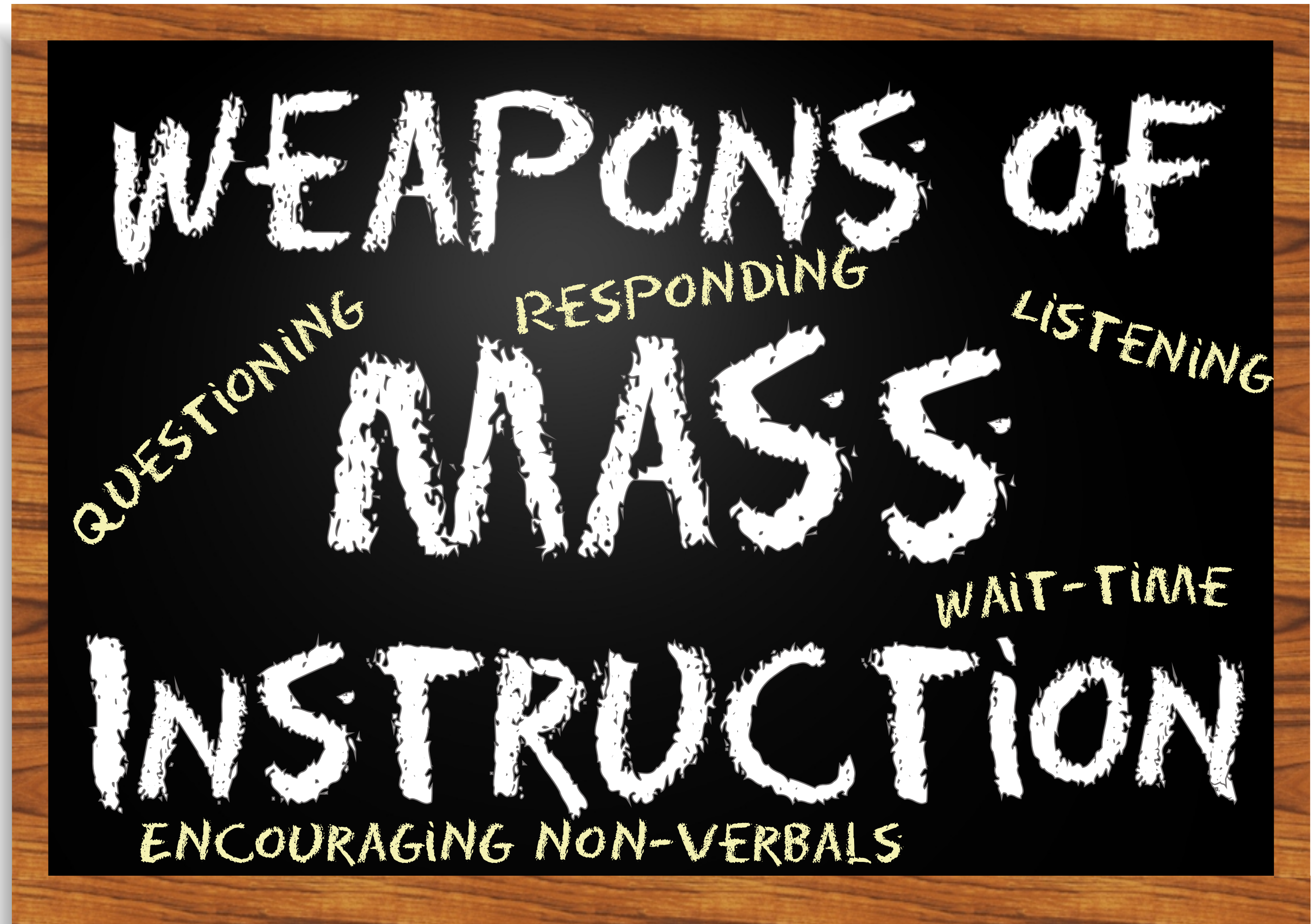

Graphic work by Joe Taylor

THE TEACHER'S CRUCIAL ROLE IN PROMOTING A DEEP UNDERSTANDING OF CONSERVATION OF MASS

by **Matthew Moffitt and Joseph Miller**

ABSTRACT: Conservation of mass is a counter-intuitive idea that students struggle to fully comprehend (Stavy, 1990). This article presents a modified version of a conservation of mass demonstration found at http://galileo.phys.virginia.edu/education/outreach/8thgradesol/ConservMatter.htm. The original activity has much potential, but here we make clear the teacher's role that is necessary for promoting inquiry and deep mental engagement. We also discuss the use of several instructional "weapons" we have successfully used to enhance learning: questioning, wait time, listening, and nonverbal communication with students. We include numerous sample questions that we ask to encourage students to share their ideas, and help students come to the desired understanding. *This article promotes High School National Science Education Standards A, B, E, and G and Iowa Teaching Standards 1, 2, 3, 4, 5,*

The idea that mass is conserved in chemical reactions is fundamental to understanding chemistry, yet is a difficult concept for many students to truly comprehend. This is understandable given that many everyday experiences, without deeper analysis, appear to contradict this idea. Burned wood apparently leaves only ash. Boiled water appears to change into gas, that students in turn often interpret as having no mass. These and other common examples provide ample evidence which students use to rationalize their misconceptions. Understanding conservation of mass is further clouded by confusion regarding the definitions of mass, weight, volume, and matter.

The counter-intuitive nature of mass being conserved in chemical reactions demands that instruction go well beyond simply telling students about this fundamental idea and then providing examples to illustrate it. Examples and demonstrations, by themselves, do not place students in a position where they must wrestle with the counter-intuitive nature of the idea and resolve the discord often lurking under the surface. The role of the teacher is crucial in mentally engaging students and creating cognitive dissonance in ways that push students to wrestle with what happens to mass that appears to "go away".

The Demonstration

The original demonstration we came across for illustrating the conservation of mass appears in Figure 1. The materials required are quite simple and consist of the following: 250 mL beaker, 250 mL flask, white vinegar, steel wool, balloon,

FIGURE 1
Procedure for Original Conservation of Mass Demonstration

Procedure
1. Tear off an egg sized piece of steel wool. Do not compress the steel wool.
2. Place the steel wool into the 250 mL beaker and add white vinegar until the entire piece of steel wool is immersed. Soak for 5 minutes to remove the oxidized steel that coats the steel wool.
3. Remove the steel wool from the vinegar. Shake off any excess vinegar.
4. Place the steel wool into the 250 mL flask and cover the opening of the flask with a balloon.
5. Mass the entire steel wool-balloon-flask system and record.
6. Let this system sit for 30-45 minutes.
7. Observe the results and again take the mass of the steel wool-balloon-flask system and record.

and a balance or appropriately calibrated electronic scale. The original activity did not address the teacher's role during the demonstration. Without extensive teacher effort to mentally engage students in demonstrations, they too often become a "watch the phenomena that the teacher is showing us" event. What follows is how we engage students in a conservation of mass demonstration, but the general approach is applicable to all demonstrations.

A Mentally Engaging Demonstration

Day 1

We don't show students the procedure in Figure 1, but as you will see in the following description, as we move through the demonstration, we require students to think about each step we go through and sometimes have them determine what must be done.

Promoting students' mental engagement in and desired learning from demonstrations obliges teachers to ask questions that draw out students' thinking and help them move their understanding forward. For these questions to effectively engage students, wait time I and II (Rowe, 1986) and encouraging non-verbal behaviors are also required. Moreover, asking students to elaborate on their responses and using students' responses in further questioning is also important (Clough, 2007). Some examples of questions we ask prior to beginning the demonstrations are:

- What is the chemical make-up of steel wool?
- If steel wool sits out in the open air, what will happen to the steel wool?

If a student responds using some form of the word "oxidize", we follow with questions such as:

- What does the term oxidize mean?
- If oxidation occurs, how would this change the appearance of the steel wool?

We continue to ask questions that encourage students to think about what we are doing at each step in the demonstration. These are at times simply questions that ask students to consider the rationale behind steps in the procedure (Clough, 2002). For example:

- What do you think the vinegar will do to the outer coating of the steel wool?

We hold up the steel wool and have students notice that the steel wool is easily compressed. We then ask:

- What is the importance of not compressing the steel wool prior to placing it in the vinegar?

Having students predict (Penick et al, 1996; Penick & Bonnstetter, 1993) what the vinegar will do to the steel wool makes more likely they will watch the resulting reaction because they want to see if their speculation was correct. When students see how shiny the steel wool is after having reacted with the vinegar, they will likely understand that compressing the steel wool would have interfered with the vinegar contacting the steel wool's surface and would have interfered with the chemical reaction. Return to this question if, prior to observing the effect of the vinegar on the steel wool's surface, students struggled to understand this important step in the procedure.

Prior to removing the steel wool from the vinegar, have students predict what will happen to the steel wool when it is taken out of the vinegar. Answers typically include "nothing," "the steel wool will lose its shine," and "it will oxidize." Before continuing, ask:

- What change, if any, do you expect to see in the mass inside the flask?
- How could we determine what is happening to the mass inside the flask?

Students will suggest massing the system before and after any observed change. Follow this with:

- How should we go about measuring the mass of the system before the change?

Students typically suggest two main ideas: (1) mass all elements (flask and steel wool) together and (2) mass each element separately and add them together. We ask students to consider the pros and cons of each method. For example, a con of using the method of massing each element separately is that unavoidable measurement uncertainty accumulates with each measurement.

Now remove the steel wool and ask students:

- What is the importance of removing all the vinegar we can from the steel wool?

Now place the steel wool in the dry flask and permit the change to occur for 30-45 minutes while you go on to another task. For example, you might review physical and chemical changes and have students determine what kind of change is illustrated in the demonstration. We have students think about the following questions:

- What are some examples of chemical/physical changes we have seen in class?
- What are some characteristics of chemical/physical changes?
- What evidence do you have to support what kind of change occurred?

We then have students discuss with a partner their ideas, write their ideas on white boards (2' by 2' marker boards) and share their ideas with the class. Meanwhile, the reaction between the steel wool and air is continuing.

When students clearly note the change of the steel wool, ask them how they can determine what has happened to the mass of the system. They will have you mass the flask and steel wool once again and find that the mass has gone up. End class with the question

- From where did that additional mass come?

Day 2

Begin the class period having students summarize the previous day's demonstration, and again ask them to speculate where the additional mass came from. Do the demonstration again, but this time before massing the system, place a balloon over the mouth of the flask. Ask students:

- Yesterday our "system" included the flask and the steel wool. What does this new system entail?
- What does the balloon prevent from occurring?

Go on to another task while the reaction occurs, but be prepared for students to look up often, note the balloon moving into the flask, and talking about what is going on. When the reaction has sufficiently occurred, ask students how they think the mass of the system (in this case, the flask, steel wool, balloon and gas in the flask) will compare to that measured prior to the reaction. When they determine that the mass of the system is essentially unchanged, ask questions such as:

- During the reaction what changes occurred?
- Why do you think the balloon moved into the flask?
- How do you account for the results of this test compared to the results of the test without the balloon covering the mouth of the flask?

Students will likely note that the balloon placed over the mouth of the flask keeps substances from moving in or out of the flask. This is an opportune time to ask:

- What is prevented from entering into the flask?
- If air cannot move into the flask, how can the reaction still occur?

At this point some students will begin to speculate that something in the air is reacting with the steel wool, and with the balloon over the mouth of the flask, something in the air that is in the flask is reacting with the steel wool. Now ask:

- Yesterday the mass of the open system increased. Where do you think that additional mass came from?
- How might that account for the mass in this closed system staying the same?

Students are now in a position to profit from being told that the chemical reaction they have been observing is the iron that makes up the steel wool reacting with oxygen gas in the air to form Iron (III) oxide in the following reaction:

$$4Fe(s) + 3O2(g) \rightarrow 2Fe2O3(s)$$

After having given this information, ask:

- In the open system that we explored yesterday, where did the additional mass come from?
- In the closed system that we have seen today, why did the mass remain the same?

Many students will now grasp that in the open system the oxygen in the air combined with the steel wool and air moved into the flask to replace that volume of oxygen gas that reacted. In the closed system, the oxygen gas in the flask combined with the steel wool, and this created a pressure difference between the inside and outside of the flask. However, the system remained closed and the mass gained by the reaction of the steel wool and oxygen gas was equal to the mass of oxygen gas consumed in the closed system. Even though some students will not yet have grasped all this, they are still in a better position to understand the explanation provided by their peers and the teacher. The key is that the abstract concept is now linked to important concrete experiences that you and students can refer back to.

Demonstrations Should Be Active Learning Experiences

Learning science through inquiry can occur with teacher led demonstrations. However, to help students truly understand desired concepts, teacher led demonstrates must mentally engage students throughout the process. Beginning with concrete experiences and moving to more abstract ideas promotes mental engagement, but these alone are insufficient. The teacher's role in involving students throughout the experience and helping them make the desired links is crucial. The questions we have provided are not a script, but they do capture the general progression of the activity. However, at all times teachers must be prepared for novel responses that call for questions and further testing to help students make desired connections. This “in-flight” decision-making is one of many reasons why teachers will always be central to effective teaching and learning (Clough, 2007).

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