Using Minute Papers to Improve Lecture Demonstrations

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ABSTRACT

Minute papers are brief papers written at the end of a lecture in response to one or two questions posed by the instructor. The answers are discussed briefly at the beginning of the next lecture. We used minute papers to follow students' understanding and response to lecture demonstrations in an introductory general chemistry course. An analysis of these minute papers suggest that the following characteristics are important, when using demonstrations as teaching aids. 1) The purpose of a demonstration should be stated as explicitly as possible. 2) Instructors should be explicit about what is happening and what students should be looking for .3) Demonstrations should be kept as simple as possible, perhaps illustrating one concept. Finally, we note that students believe that the visual component of demonstrations enhances their comprehension of chemistry concepts.

Key words: minute papers, lecture demonstrations, teaching aids

I. Introduction

Lecture demonstrations are often employed during chemistry lectures as visual aids to focus students attention on chemical behavior and properties, help build up general experimental knowledge, promote student comprehension, stimulate student enthusiasm, help students make the connections between theory and reality, stimulate thought processes, and "teach chemistry" (Beall, 1996; Bodner, 2001, Ramette, 1980; Sanger, *et al.*, 2000; Shakhashiri, 1983; Tannis, 1984). Bowen and Phelps (1997), suggest that using demonstrations as instructional tools for assisting student learning can help students make links between symbolic representations usually presented in lecture format and macroscopic chemical phenomena that chemists experience in day-to-day work. Bowen and Phelps (1997), and Deese, Ramsey, Walczyk, and Eddy (2000) also describe several ways to use demonstrations to measure student learning in chemistry. However, instructors often do not know what kind of ideas, scientifically correct or not, are developed by students watching demonstrations. Therefore, it is uncertain whether our efforts in presenting demonstrations are justified--beyond the indisputable benefit of attracting the student's attention (Gattis, 1997).

Although it has been reported that demonstrations increase the level of student attention and involvement in the science classroom (Beasley, 1982), a few other studies show that students' interpretations of demonstrations differ from their teachers' intentions (Shepardson, Moje, and

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Kennard-McClelland, 1994, p. 244), and that demonstrations may not have the instructional impact intended (Tobias and Hake, 1988). A study in which ten distinguished professors from non-physical science disciplines studied physics showed that while these professors found that the demonstrations used were enjoyable, they did not significantly enhance their understanding of the subject (Tobias and Hake, 1988). Roth *et al.* (1997) report several reasons why students may not learn from demonstrations: Students may lack the theory or background to recognize the important aspects of a demonstration; they may interpret the demonstration in terms of other contexts seen in the course or in other courses; they may not have enough prior knowledge to understand the information in the demonstration in terms of the course content; they may not believe that understanding the demonstration is important to their grade in the course; or they may lack opportunities to test their understanding and explanations of the demonstration.

In view of the reports described in the previous paragraph, anecdotal information from our colleagues, and our own observations, we developed the following Research Questions:

(1) What do students "see" (observe) when a demonstration is performed in a lecture?

(2) Do students "see" (interpret) what the lecturer intended?

(3) Do students "see" (understand) the relationship of a demonstration to the lecture content?

We set out to answer these questions by analyzing minute papers students wrote in response to their instructor's questions about the demonstrations performed in a general chemistry course.

The minute paper (Cross and Angelo, 1993; Wilson, 1986) is a widely used teaching strategy that encourages active learning by students, and provides feedback to teachers. The use of minute papers as a teaching strategy is simple: Give students the last few minutes of class to write a short answer to one or two specific questions asked by the instructor, collect and review the answers, and respond in some way during the following class period. Minute papers are short. Generally they are limited to an index card or a half-sheet of paper. In our case, the questions related to demonstrations performed by the instructor.

Ⅱ. Methodology

In order to obtain the data to answer our research questions, we enlisted the help of the instructor of a two-semester, introductory general chemistry course for students of agriculture, nursing, and technology at a large Midwestern university. The population of this course consists of both traditional and nontraditional students. One hundred forty of the students in the course allowed us to photocopy and analyze the minute papers that they wrote in response to questions posed by the instructor regarding several demonstrations that were performed during the course. The minute paper questions fall into three categories:

(a) Today I did a simple demonstration, tell what you saw.

(b) Why do you believe I did this particular demonstration?

(c) Did you find value in it?

Questions of type (a) provide data that we believe address Research Questions (1) and (2). Questions of type (b) provide data to answer Research Questions (2) and (3), while questions of type (c) provide data to answer Research Question (3). Students wrote their observations, opinions of the relation of the demonstration to the lecture material, and their assessment of the value of the demonstration(s) to their learning. The demonstrations and questions used with each demonstration are listed in Table 1.

Table 1. Description of demonstrations and corresponding one-minute paper questions

Description	Questions
Display of a bulb emitting white light and a neon light emitting red light.	1. Today I did a demonstration involving light. Tell me what you saw. 2. Do you believe the demo helped with the lecture material?
Ignition of a balloon containing hydrogen and oxygen and igniting the acetylene gas in a calcium carbide cannon.	1. Today I did a demonstration. Tell me what you saw. 2. Why do you believe I did this particular demonstration?
Addition of molten metallic sodium to a flask containing chlorine gas.	1. Why do you think I did this demonstration?
Igniting a piece of paper and placing it in a jar, which was then covered.	1. Today I did a simple demonstration. Tell what you saw. 2. Why do you believe I did this particular demonstration? 3. Did you find value in it?
Addition of potassium iodide to a solution of hydrogen peroxide which contained a small amount of soap.	1. Today I did three demonstrations. Tel me about the first one. 2. Why do you believe I did this particular demonstration? 3. Was I successful?
Demonstration of a Daniell cell	1. Today I had a small demonstration. Tell me what you saw.
Addition of small amounts of strong acid and strong base to buffered and unbuffered aqueous solutions.	1. Today I had a small demonstration about buffered solutions. Tell me what you saw. 2. Do you believe the demo helped your understanding of this concept.
Decomposition of ammonium dichromate using a burning magnesium ribbon to initiate the reaction.	1. Today I had a small demonstration. Tell me what you saw. 2. What teaching point do you think I was making? 3. Do you believe the demo helped your understanding of this concept?
Display of a working Geiger counter.	1. Today I had a small demonstration. Tell me what you saw.

We analyzed the minute papers collected during the course. Responses generally fell into a limited number of categories. Table 2 lists responses and categories for the ignition of a hydrogen balloon. The responses have been separated and compared using cross case analysis, which involves comparison of all the students' responses, to individual questions (about a particular demonstration) to each other, then grouping the responses into descriptive categories according to similarity of responses. The responses were also analyzed within cases, which involved analyzing a particular students' response to all questions on a particular one-minute paper, in order to correlate their visual observation to their conception of how that particular demonstration was related to the content of that particular lecture. These responses were then compared to the lecture notes to determine the source of their interpretations. The responses to all demonstration have also been compared to each other in order to identify any overall similarities. Finally, the responses were compared to the instructor's perspective of the pedagogical objective of the demonstrations. This perspective was obtained in discussions with the instructor.

What do students "see" (observe) when a demonstration is performed in a lecture.

With few exceptions, our students reported observations which were consistent with those the instructor wished them to see, in their responses to the question "Today I did a simple demonstration, tell what you saw." Demonstrations of reactions were generally described in one of two ways: as a reaction of one or more substances, or as the physical phenomenon accompanying the reaction. Students who saw the reaction of hydrogen and oxygen typically commented.

[I saw] "... the reaction of H_2 and O_2"

Table 2. Typical responses and categories for the hydrogen balloon demonstration

Question 1: Today I did a demonstration. Tell me what you saw.

Examples of response
I saw a visual demonstration of a <u>chemical equation</u> in effect*
A reaction that gave off a lot of kinetic <u>energy</u>.
A balloon goes up into <u>flames</u>.
A <u>fire ball</u>.
<u>Exploding</u> balloon
I saw the <u>reaction</u> of H_2 and O_2
Ambiguous response

* underlined words represent the categories

Question 2: Why do you believe I did this particular demonstration?

Description of response
To demonstrate an <u>equation</u>.
To show the <u>energy</u> produced.
To demonstrate <u>combustion</u>.
To show reaction <u>type or classification</u>.
To demonstrate <u>synthesis</u>.
To show a (chemical) <u>reaction</u>.
To teach us <u>visually</u>.
Keep attention or keep interest.
No idea / don't know
Ambiguous response

* Underlined words represent the categories

Observation of a physical phenomenon accompanying the reaction is illustrated by

[I saw] "... a balloon go up into flames."

"The orange "pile" with magnesium strip in it was changed after the Mg was lit. It went from orange to dark green fluffy powder. The sparks were neat."

Almost all students watching the demonstration of the important components of the behaviors of buffered and unbuffered solutions reported the physical phenomena associated with the addition of acid or base. Over 90 percent of the students stated that they saw a comparison of the effect of acid or base on buffered and unbuffered solutions. A couple of typical responses are:

"I saw how the buffered solutions did not fluctuate when a strong acid was added and how H_2O changed colors due to not being buffered."

"A non-buffer solution (H_2O) was greatly effected by the acid/base added. The buffered solution was not affected."

Other responses were similar, with the only differences being whether or not specific reference was made to pH changes, acid, base or color change. Even those students who did not understand buffers observed the salient data from the demonstration. For example, a student who said the buffer demonstration only somewhat improved his understanding still saw "... two test tubes change colors and the buffers stayed the same."

Typical reports from the demonstration of a Daniell cell suggest that fewer students picked up all of the observations relevant to this more complex demonstration which involves a zinc; zinc-ion half cell; a copper; copper(II)-ion half cell; an external circuit; a voltmeter; and a salt bridge. The more complete statements include

"What I saw--how the difference of separating the Zn and Cu and providing the electrodes and salt bridge allowed for the voltmeter to measure the change in electron transfer"

"The development of a current producing Daniell cell."

Less complete observations were recorded as

"I saw the Cu strip turn black and the Zn strip turn black."

"Piece of metal sitting in blue stuff."

"I saw how the flow of electrons could generate energy."

One student misunderstood completely:

"Cu was plated onto Zinc."

The most common incorrect statements in students' reports of their observations were statements of an inference, rather than the observation on which the inference was based. For example, the student who states he or she saw a pH change was inferring the pH change from the change in the color of an indicator.

"I saw that when you add an acid or base to pure water the pH changes a lot, but when you add acid or base to a buffered solution, the pH doesn't change as much or hardly at all".

A description of the Daniell cell read

"It helped to show how the electron move through the solutions [and] are transferred from one reactant to another."

A few students confused reported seeing a microscopic phenomena rather than the observable macroscopic effects produced by the microscopic phenomena. For example,

"I saw the actual transfer of electrons from zinc and copper moving form one state to another"
"I saw ions being exchanged and the ending being electricity"
"I saw ionic bonds and energy" (in the reaction of sodium with chlorine).

Do students "see" (interpret) demonstrations as the lecturer intended?

In most cases students in our study interpreted demonstrations as the instructor wished them to, probably because the demonstrations were simple or were carefully explained. Even those students who did not understand buffers observed the salient data from the related demonstration. For example, a student who said the buffer demonstration only somewhat improved his understanding still saw "two test tubes change colors and the buffers stayed the same." Students saw evidence of chemical reactions: fireballs resulting from the explosion of a hydrogen-oxygen balloon, noise produced by a carbide cannon, color changes and evolution of heat during the decomposition of ammonium dichromate, and flames when molten sodium burned in an atmosphere of chlorine gas, as evidence that a chemical reaction had occured.

It appears that the burning magnesium strip used to initiate the decomposition of ammonium dichromate served as a distraction in this demonstration: The purpose of the strip was misinterpreted by several students. Although most students said that the burning strip was used to "light the pile of orange powder" others believed that the magnesium was actually involved in the reaction:

"I saw the substance oxidizing with the magnesium, creating a bigger substance of a different color."
[I saw] "How the magnesium reacted with the reactants to produce a bigger amount of the product."

How do students "see" (understand) the relationship of a demonstration to the lecture

It would be extremely satisfying if responses to the question, Why do you believe I did this particular demonstration?, were of the quality of "You were showing a tangible example of a balanced redox reaction." and "Yes it helped me to understand that a buffer system actually already has the acid and salt introduced to the system before the addition of strong acid/base" However, these were not the typical responses seen at the beginning of the course. Initially, many students did not make the expected pedagogical associations between a demonstration and the contents of the lecture. Early on, students often gave ambiguous responses such as "improving our understanding" or "keeping our interest". These responses were offered for each demonstration by a significant number of students. Apparently they may have made no connection between the demonstration and the content of the lecture.

With experience, students increasingly related the purpose of the demonstrations to chemical concepts rather than giving ambiguous responses, but many of the concepts reported related to ideas other than those they were intended to illustrate. An example of confusing the purpose of the demonstration with other lecture topics is seen in comments about the demonstrations involving the hydrogen balloon and the carbide cannon. Students said the purpose of the demonstrations was:

> "to illustrate what the different symbols in the chemical reaction actually stood for".
> "to show the amount of energy produced."

The instructor's intention actually was to demonstrate different classes of reactions, in this case, a synthesis reaction and a combustion reaction.

As time went on, students made more of the pedagogical associations desired by the instructor. With the exception of those related to the demonstration of a Geiger counter, none of the minute papers analyzed during the second semester of the course contained the ambiguous responses, and most responses related directly to chemical concepts, whether or not the respondent had grasped the purpose of the demonstration.

Many students read more into a simple demonstration of a phenomena than intended by the instructor. For example, one student's response to the question of what was seen when a light bulb and a red neon light were displayed, read, "The incandescent light only took two lines on the spectrum." In this case, the instructor had given a description of how light was produced, but the demonstration did not include a display of line spectra.

Students appear better to understand the purpose of a demonstration that illustrates a concept than the purpose of a demonstration that illustrates a reaction or process. For example, when the instructor burned paper in a jar, and then covered the jar to put out the flame, (a demonstration he related to limiting reagents), a large majority of students said that the purpose of the demonstrations was "to show limiting reagents" or "to show oxygen being the limiting reagent". When an oxidation-reduction reaction was demonstrated, the answer to the question, what teaching point do you think I was making?, (with the decomposition of ammonium dichromate) drew confused responses such as

> "I wasn't sure whether you were showing us the activation or whether it was balancing or whether it was redox."

Although the italicized concepts were mentioned at different points during the course of the lecture in which this demonstration was performed, the topic and main focus of the demonstration was to illustrate an oxidation-reduction reaction. The idea of activation was mentioned prior to the demonstration by the instructor who noted, as an aside, that the reaction had a high activation energy for its initiation and required a burning magnesium reaction as an igniter. The lecture also included balancing oxidation-reduction equations both before and after the demonstration was performed.

Ⅲ. Conclusions

To our knowledge, there are no other studies of the level of student understanding of chemistry demonstrations at the high school or college level. However, our study does indicate that chemistry students have many of the same difficulties interpreting chemistry demonstrations as high school physics students have interpreting physics demonstrations. (Roth, *et al.*, 1997). These are (i) students' inability to separate signals from noise because they do not have the necessary knowledge to identify the key components of a demonstration, (ii) interference of information learned in other portions of the course, (iii) interference from other demonstrations having some surface resemblance, (iv) students' problems in connecting the point of the demonstration with the content of the lecture.

In Chemical Demonstrations, Volume 1, Shakhashiri (1983, p. xix) quotes Wesley Smith's six characteristics of effective demonstrations which best promote student understanding. Smith notes that demonstrations must be (1) timely and appropriate; (2) well prepared and rehearsed; (3) visible and large scale (4) simple and uncluttered (5) direct and lively; and (6) dramatic and striking. Students' minute papers suggest that the following characteristics are also important when using demonstrations as teaching aids in order to help students avoid the difficulties noted above.

(1) The purpose of a demonstration should be stated as explicitly as possible. The comments on our minute papers suggest that some students are unsure of the context of demonstrations and the chemical concept which they demonstrate. Specific statements relating the purpose of a particular demonstration would allow students to make the correct pedagogical association and reduce confusion about the context of a demonstration.

(2) Instructors should be explicit about what is happening and what students should be looking for. Explicit references to key features of demonstrations would insure that students focus on the appropriate aspect of the demonstration and its relationship to the concept being discussed. For example, in preparation for a demonstration of the effect of acid or base on buffered and unbuffered solutions, tell students that the color of the indicator is a measure of the concentration of hydrogen ion in the solutions and ask them to watch for changes as you add acid or base.

(3) Demonstrations should be kept as simple as possible, perhaps illustrating one concept. Analysis of student responses indicate that students make the correct pedagogical association for the simpler demonstrations. This suggest that a simpler demonstration may increase the signal-to-noise ratio and be more effective as a teaching tool than a more complex demonstration of the same behavior. Instructors should try to choose lecture demonstrations of the least complexity.

Finally we note that some students believe that the visual component of demonstrations enhances their comprehension of chemistry concepts. For each of the demonstrations, in response to "Did this demo help your understanding of the concept?", a significant number of students stated that "It helped to see" or made some reference to the fact that the visual aspect of the demonstration was helpful in understanding the concept being taught. For the demonstration concerning buffers, 93 percent of student responses stated that the demonstration helped them to understand the concept. This is significant because in the previous lecture the instructor presented a mathematical explanation to the students. Some respondents made specific reference to the fact that the visual demonstration was more effective than the mathematical explanation.

References

Beall, H. 1996. Report on the WPI conference Demonstrations as a teaching tool in chemistry: Pro and con. *Journal of Chemical Education*, 73, 641-642.

Beasley, W. 1982. Teacher demonstrations: The effect on student task involvement. *Journal of Chemical Education*, 59, 789-790.

Bodner, G. M. 2001 Why lecture demonstrations are 'exocharmic' for both students and their instructors. *University Chemical Education*, 5, 31-35

Bowen C. W., and Phelps, A. J. 1997. Demonstration-based cooperative testing in general chemistry: A broader assessment-of-learning technique. *Journal of Chemical Education*, 74, 715-719.

Deese, William C.; Ramsey, Linda L.; Walczyk, J.; Eddy, D. 2000. Using demonstration assessments to improve learning. *Journal of Chemical Education*, 77, 1511-1516.

Driver R., and Bell, B. 1986. Student's thinking and the learning of science: A constructivist view. *School Science Review*, 67, 443-456.

Driver R., and Oldham, V. 1986. A constructivist approach to curriculum development in science. *Studies in Science Education*, 13, 105-122.

Erickson, F. 1986. Qualitative methods in research on teaching. In M. Wittrock Ed., *Handbook of research on teaching*, Vol. 3, pp. 119-161. New York: Macmillan

Gattis, K. W. and Park, J. C. 1998. Effectiveness of demonstrations in facilitating physics concept acquisitions. Paper presented at the annual meeting of the National Association for Research in Science Teaching.

Patton, M. Q. 1990. *Qualitative evaluation and research methods*. Newbury Park, CA: Sage.

Ramette, R.W. 1980. Exocharmic reactions. *Journal of Chemical Education*, 57, 68-69.

Roth, W. M., McRobbie, C. J., Lucas, K. B., and Boutonne, S. 1997. Why may students fail to learn from demonstrations? A social practice perspective on learning in physics. *Journal of Research in Science Teaching*, 34, 509-533.

Sanger, Michael J.; Phelps, Amy J.; Fienhold, Jason. 2000. Using a computer animation to improve students' conceptual understanding of a can-crushing demonstration. *Journal of Chemical Education*, 77, 1517.

Shakhashiri, B. Z. 1983. *Chemical demonstrations: a handbook for teachers of chemistry, Vol. 1* Madison, WI: University of Wisconsin Press.

Shepardson, D. P., Moje, E. B., and Kennard-McClelland, A. M. 1994. The impact of a science demonstration on children's understandings of air pressure. *Journal of Research in Science Teaching*, 31, 243-258.

Tannis, D.O. 1984. Why I do demonstrations. *Journal of Chemical Education*, 61, 1010.

Tobias, S. and Hake, H.H. 1988. Professors as physics students: What can they teach us? *American Journal of Physics*, 56, 786-794.

van Manen, M. 1990. *Researching lived experience: human science for an action sensitive pedagogy* pp. 1-34. New York: State University of New York Press.

von Glasersfeld, E. 1989. Cognition, construction of knowledge, and teaching. Synthese 80, 121-140.