Favorite Demonstrations

for College Science

Brian R. Shmaefsky, Editor

An NSTA Press Journals Collection

NSTA press®
NATIONAL SCIENCE TEACHERS ASSOCIATION
Arlington, Virginia

NSTA press
NATIONAL SCIENCE TEACHERS ASSOCIATION

Claire Reinburg, Director
Andrew Cocke, Associate Editor
Judy Cusick, Associate Editor
Betty Smith, Associate Editor

Journal of College Science Teaching Lauren Beben, Managing Editor

Art and Design Linda Olliver, Director
Printing and Production Catherine Lorrain-Hale, Director
Nguyet Tran, Assistant Production Manager
Jack Parker, Desktop Publishing Specialist
*Sci*LINKS Tyson Brown, Manager
David Anderson, Web and Development Coordinator

National Science Teachers Association
Gerald F. Wheeler, Executive Director
David Beacom, Publisher

06 05 04 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Favorite demonstrations for college science : an NSTA Press journals collection / Brian R. Shmaefsky, editor.
p. cm.
Includes index.
ISBN 0-87355-242-3
1. Science—Study and teaching (Higher) 2. Communication in science. I. Shmaefsky, Brian
Q181.F28 2004
507'.1'1—dc22

2003027269

Featuring SciLinks®—a way to connect text and the Internet. Up-to-the-minute online content, classroom ideas, and other materials are just a click away. Go to page xvi to learn more about this educational resource.

About the Cover—Safety Issues: The cover illustrates a classical Van de Graaff generator demonstration used to excite physics students for many years. Today, this demonstration should only be conducted under the supervision of a competent operator of the generator. High voltage passes through the body during contact. That is what caused the funky hairdo in the student who volunteered to have his body loaded with electrons. A demonstration such as this one can still be done. However, strict precautions must be exercised. It should only be done on healthy volunteers who do not have any prosthesis that can be affected by the electrical current (e.g., a pacemaker or other implanted device). Plus, it is best to do any Van de Graaff generator demonstration away from computers and instruments sensitive to electrical discharge.

Contents

Physical Sciences

Introduction

"To be fruitful in invention, it is indispensable to have a habit of observation and reflection."

—Abraham Lincoln
February 11, 1859

Lincoln's comment truly reflects the nature of successful college science teaching. Teaching higher-order-thinking skills in science is best achieved by having students examine and reflect about the scientific principles behind their observations. This can be achieved in many ways through a combination of classroom instruction and laboratory experiences. Classroom demonstrations are a popular way of stimulating students to carefully witness and process scientific principles.

A multitude of educational research studies published over the past 30 years supports the use of demonstrations in teaching. Demonstrations reinforce learning by allowing students to visualize abstract scientific concepts as concrete expressions. They particularly help students who rely on visual learning cues to better understand the concept. Demonstrations are also entertaining and foster learning by linking two or more senses with positive emotional imagery. In other words, students keep facts and concepts in their minds longer when the information presented to them is enlivening and easy to recall. Students are more likely to remember complex topics such as thermodynamics when they see a demonstration that accurately portrays the principles.

This book is a compilation of peer-reviewed classroom demonstrations tailored to upper-level high school and college science teaching. All of them were published between 1993 and 2003 in the "Favorite Demonstration" column of the *Journal of College Science Teaching*. These demonstrations were selected for this compilation because they accurately convey scientific principles in a manner that kindles student inquiry. Many of them are useful as "attention grabbers" for science talks to young children and the public. However, these demonstrations alone do not instill science learning. They are part of an overall instructional strategy that convinces students to seek a complete understanding of scientific doctrine.

The first two sections of this book are applicable to all science disciplines. They present demonstrations that illustrate laboratory safety and general scientific principles. After all, each science discipline shares the common threads of scientific method and experimental techniques. The latter two sections, Natural Sciences and Physical Sciences, were difficult to assemble. Many of the demonstrations exhibited principles that spanned the artificial delineations between the sciences. So, they were placed into categories based on where the concepts are commonly taught in introductory college science classes. Teachers can browse through both sections for demonstrations that touch on topics taught in any science discipline.

Each demonstration uses equipment and materials that are currently available from scientific supply companies or local stores. However, the costs of the items may have changed since the original publication date. Overall, most of the demonstrations are inexpensive and simple to carry out. They also require a minimum of

precious classroom time. Some of the demonstrations can be modified into student inquiry activities or laboratory sessions. How the demonstrations are used is up to the instructor, who can adapt or modify the demonstrations to particular instructional needs.

Dr. Brian R. Shmaefsky
Column Editor, "Favorite Demonstration"
Journal of College Science Teaching
Kingwood College, Kingwood, Texas

About the Editor

Brian Shmaefsky is a professor of biology and the service learning coordinator at Kingwood College in Kingwood, Texas. He went from co-editor to editor of the "Favorite Demonstration" column in the *Journal of College Science Teaching* and has served the column for 10 years. Dr. Shmaefsky regularly teaches with demonstrations he adapted from his experiences as a biochemist for Sigma Chemical Company and from 20 years of college teaching. He has published dozens of papers and presented almost an equal number of presentations on science education and training. Dr. Shmaefsky has also authored books and trade journal articles about biotechnology, human disease, and technology transfer. He has two children, 12-year-old Kathleen and 15-year-old Timothy, who assisted in several science teaching articles, including two that appear in this book. Dr. Shmaefsky lives in north suburban Houston with his dog, Dusty.

The Rules of Research

Keeping Your Favorite Demonstrations Safe

Brian R. Shmaefsky

Demonstrations are wonderful educational strategies for reinforcing and stimulating learning. They are highly instructional as well as entertaining if suitably incorporated into lectures and laboratory sessions. This is not a biased, unsubstantiated opinion, but rather the reflection of a 20-year investigation of the role of demonstrations in college science teaching. Unfortunately, the educational value of demonstrations may be clouded by an ignoble side. Many faculty members fail to recognize that demonstrations used in biology, chemistry, and physics have equivalent hazards as laboratory activities.

Any demonstration using chemical or physical reactions should be carried out with the same alacrity and precautions used when conducting instructional laboratories. Of the utmost importance is avoiding hazardous situations by doing demonstrations that are not dangerous. Instructors must consider the learning value of using explosions, incendiaries, fuming reactions, or projectiles before planning demonstrations. Several questions should be considered: Do the potential risks of the demonstration justify the gain in educational outcomes? Can the same concept be presented using another demonstration? Would the demonstration have equal impact using a multimedia presentation? Can the activity be modeled more safely in a microscale laboratory or by using virtual laboratory software?

Faculty members who are not fully familiar with demonstration safety precautions will benefit from Internet resources. I find the following sites to be especially helpful:

- Laboratory Safety Institute, online at *www.labsafety.org*. This Web site contains many useful safety hints for conducting demonstrations and teaching laboratory sessions. Included are safety workshop opportunities and access to laboratory safety discussion lists. Safety books and fact sheets are also available on the site.
- Science Inquiry, online at *www.scienceinquiry.com*. This Web resource is predominantly directed at K–12 educators. However,

much of the information is pertinent for introductory-level college science instruction. Included in the site are demonstration ideas and lists of books and literature references on inquiry teaching.

If the demonstration is deemed appropriate, then it is imperative to observe all safety precautions outlined in the instruction manuals and Material Safety Data Sheets (MSDS) for the equipment and chemicals used. Any people carrying out the demonstration must be outfitted with appropriate personal protective equipment (PPE). Information can be obtained from the instructional manual and the MSDS. Students or spectators should also be provided with protection or PPE. Isolation of spectators using barriers or a safe distance zone is acceptable if it is not practical to provide the whole audience with PPE.

Appropriate PPE for many science demonstrations include:

- Body protection—chemical- and water-resistant aprons, gowns, or coveralls
- Ear protection—ear covers or disposable ear plugs
- Eye protection—full-wrap, splash-proof, impact-resistant goggles, or face shields
- Foot protection—fully covered shoes or boots
- Hand protection—chemical-, heat-, or impact-resistant gloves
- Respiratory protection—chemical- or dust-blocking masks or respirators (with proper ventilation)

Faculty as well as any students directly involved in demonstrations must be using PPE.

Topic: safety in the science classroom
Go to: *www.scilinks.org*
Code: JCSTC4

Emergency response measures should be in place before doing any demonstration with potential hazards for the faculty or students. Graduate students and assistants helping with the demonstration must do the following:

- Alert the laboratory coordinator or safety officer that the demonstration is being done.
- Have a plan for calmly, quickly, and safely evacuating students from the room.
- Have ready access to ample supplies of PPE.
- Know the locations of the nearest emergency exits.
- Have ready access to emergency telephone numbers for emergency responders, first-aid care, or campus police.
- Know the locations of the nearest fire alarm or emergency call boxes.
- Have a cart equipped with materials for cleaning up after an accident.
- Know the locations and conditions of the nearest fire extinguishers.
- Know the location of first-aid equipment.
- Be familiar with the location of MSDS for chemicals used in the demonstration. Check your board of education or college rules regarding the use of chemicals and banned chemicals.
- Be familiar with the location of the instruction manuals for any equipment used in the demonstration.
- Know how to expeditiously dispose of any hazardous wastes resulting from the demonstration in an appropriate manner. Check your board of education or college rules regarding chemical pickup by Hazmat.

This list may be posted or incorporated into a checklist for use before any demonstration. Copies should be available to all faculty members conducting favorite demonstrations. The safe use of demonstrations is a fundamental issue echoed in the safety statements required before any presenter can perform a session at a National Science Teachers Association convention.

Laboratory coordinators or safety officers benefit from a demonstration safety checklist. Industrial research labs use such checklists before a potentially hazardous laboratory procedure or production operation can be implemented. In the classroom, a checklist would require that cer-

tain information be completed before and after the demonstration. It could be tailored to individual needs or institutional requirements. Sample checklists are shown in Figure 1. By following these commonsense procedures, educators can confidently present demonstrations and keep learning a vibrant and enjoyable activity for science students.

figure 1 Sample checklists to be completed before and after performing demonstrations

Before the demonstration:

Date
Person(s) conducting the demonstration
Building
Room number
Office phone or extension
Approximate number of students observing
Type of demonstration: biology, chemistry, geology, or physics
Process description (describe what is being done)
Protocol steps or copy of activity
List of hazardous materials
Potential hazards or risks
Personal protective equipment for demonstrators
Personal protective equipment for spectators
Location of instruction manuals or MSDS
Safety precautions being taken
Emergency or accident procedures in place

After the demonstration:

Methods of waste disposal
Locations of used equipment
Modifications done not listed in protocols
List of unexpected incidents
Comments for next demonstration

general science principles

A Bright Idea: Reinforcing Logico-Deductive Reasoning

Jan Benjamin and Brian R. Shmaefsky

Many students in freshman- and sophomore-level science courses have little experience formulating testable hypotheses. Their typical high school and college education includes little more than a lecture on the scientific method replete with examples of experimental design. Most students also take part in conjecturing hypotheses associated with narrowly delineated laboratory activities. Teachers of large lecture sections, in particular, devote little time to guiding students' hypothesis testing.

However, an accurate comprehension of the scientific method is critical for understanding experimental design and for the success of science majors in upper-level courses and graduate programs. The typical approach to teaching the scientific method entails presenting a series of steps meant to make the logic behind the scientific method more intelligible. Unfortunately, this alone does not fully instill an understanding of testable-hypothesis generation. Students need step-by-step interaction with the scientific

figure 1 Touch lamp theory

Touch lamps operate by monitoring the discontinuity of an alternating current (AC) flowing throughout the body of the lamp. The touch lamp circuit pulses a small electrical charge into and out of the lamp body. This electrical charge is continuously monitored by a silicon chip. The chip activates a switch when the charge changes and exceeds a certain value. Apparently, the body's conductivity provides a disruption in the current that exceeds a set value for operating the switch. The switch used in the lamp is known as a flip-flop memory bit. It flips back and forth between an on and off position to operate the lamp. Many of the touch lamps use a three-way light that permits the lamp to go from dim to bright. The circuitry in the three-way lights is the same as in an ordinary touch lamp, except that the chip operates a three-way lamp switch (MadSci Network 1998).

method to get a thorough appreciation of the logico-deductive foundations of scientific inquiry (Paul and Elder 2002).

The following activity was designed to reinforce the teaching of the scientific method in large lecture sections of introductory science courses. This strategy is applicable to college-level biology, chemistry, engineering, and physics courses. Its success at boosting comprehension is well documented in the educational research on active or participatory learning (Cross 2003).

Materials

The materials for this demonstration are inexpensive and simple to obtain—it generally requires only one touch lamp to be purchased. Touch lamps lack a standard on-and-off switch, so users can touch any surface of the lamp to turn on or off the lamp (see Figure 1 for details). The touch lamp used in this activity was purchased for $10 at a national discount store chain, and almost all discount stores and furniture retailers sell inexpensive touch lamps.

This demonstration requires the following materials to be readily available:

- Touch lamp
- Overhead projector or LCD device for displaying written student responses
- Objects for touch lamp switch variables, including a piece of cloth, piece of paper, steel paper clip, aluminum can, copper coin, plastic ruler, and rubber tube
- Objects for touch lamp conclusion, including a surgical glove and salad oil

Topic: scientific method
Go to: *www.scilinks.org*
Code: JCSTC10

Procedure

Teachers can begin by giving an in-class lecture on the scientific method, with examples pertinent to the field of study being taught, and then introduce students to the touch lamp. It can be introduced as a scientific curiosity purchased while shopping. We like to tell students that we found an interesting lamp that has no switch. Then, we show the class how touching the lamp on the tip of the lamp shade turns on and off the light. We explain that the lamp shade is made of metal and sits in proximity to the lightbulb.

Teachers can then ask students to predict if touching any other part of the lamp will activate the switch. Each student who volunteers an answer should provide a written explanation for his or her prediction, which will be displayed on the overhead for the class to read.

Once students have had a chance to make predictions, we test the predictions by touching the parts students thought would or would not activate the lamp. We record the results next to the predictions, and it quickly becomes apparent that touching any portion of the touch lamp body will turn on or off the light. However, students should note that touching the cord is ineffective. We follow this up by telling students that we think pressure on the lamp's surface activates the switch. Then, we ask them to come up with a way to test this hypothesis.

After soliciting several hypotheses, we touch the lamp with each of the materials brought in as a switch variable. Students will notice that not all of the objects cause the lamp to turn on or off. They should then come up with another hypothesis for how the lamp switch works.

We immediately announce to the class that we have another hypothesis: It is the skin's electrical conductivity that makes the lamp switch work. The class debates this hypothesis and determines whether the materials can act as a conduit for the skin's conductivity.

Eventually, we tell the class that we have a way to test the new hypothesis. We put on a surgical glove, touch the lamp, and show the class that the lamp continues to switch on and off. We then suggest that the glove may be too thin to cover up the skin's electrical conductivity. So, we announce that we will reduce the skin's conduc-

tivity by coating one finger with salad oil. We touch the lamp again and note that the switch does not operate. This is a good time to ask students to summarize how logico-deductive reasoning is used to come up with experimental designs to test hypotheses.

The low cost of touch lamps makes it feasible to design a laboratory activity around them. So, for a further extension of this demonstration, students working in groups of two or three can develop hypotheses about the switch mechanism. Teachers can give the class access to materials they can use to test the lamp's operation.

Student Evaluation

Student evaluation of the activity shows that the novelty of the activity improves attentiveness. The great focus on the demonstration enhances learning of scientific method applications. Test performance on science method questions is higher for students who participated in this demonstration, as compared to students attending the traditional lecture format. Students taking part in the demonstration scored an 85 average on scientific method multiple-choice and essay questions, as compared to the 70 average scored by those who were not involved in the activity.

Acknowledgment

We thank the Kingwood College students enrolled in Biology 1406 and Biology 1408 for their help in evaluating the effectiveness of the touch lamp demonstration.

References

Cross, P. K. 2003. *Techniques for Promoting Active Learning*. Phoenix, AZ: League for Innovations in the Community College.

MadSci Network. 1998. *Engineering: How Does a Touch Lamp Work?* Available online at *www.madsci.org/posts/archives/may98/893276774.Eg.r.html*.

Paul, R., and L. Elder. 2002. *How to Improve Student Learning*. Dillon Beach, CA: The Foundation for Critical Thinking.