Dan, yahoo will not let me attach this as a word file.  Hopefully you can copy and paste it over if you want.  I shortened the beginning part to a little under 2 pages.  I couldn't get it down to 1 page.  Perhaps you could recommend sections to axe.  I also changed the second part to "Nature of Science with a 3-way Bulb."  I keyed in on day 1 as batteries and bulbs and day 2 getting right into the 3-way bulb lesson.  I think this is how I will teach it this year (coming up shortly).  I've always done the 3-way bulb lesson a little later on in the past, but this year I'm going to try in on the 2nd day of electric current.  Please let me know what you think.  I'm getting very anxious to complete this paper and graduate (and keep my job).  I'm kicking myself for procrastinating this long.

Also, would you be the person to check with to make sure I've completed all other requirements besides PHY 690 for the Alt-Cert Master's degree in Physics Ed?  My certification expires August 31 of this year, so I very much need a May graduation and to get the paperwork into State Ed asap.   I have some printouts from about 5-6 years ago of Alt-Cert requirements and I'm pretty sure I've met everything, as long as nothing has changed while I've been away.

Thank you very much.

Regards,

Dan Graf

The \*\*\*\* are places I need to put some citations in.

Abstract:

This article aims to describe an activity to introduce students to the scientific process using a novel situation: a 3-way light bulb.  We often introduce students to light bulbs through exercises involving simple DC circuits with batteries and miniature light bulbs.  Though these experiments have great merit in exposing students to ideas of current flow and resistance, they do not fully invoke the scientific process.  Using 3-way bulbs, we can extend these experiments to draw testable hypotheses from our students.  Allowing our students to explore 3-way bulbs turns our students into scientists.

Recognizing Traditional Teaching and Lab Work

In recent years, a significant wealth of knowledge has been gained in the art and science of teaching physics.  There is becoming perhaps an overwhelming amount of Physics Education Research (PER) to sort through.  What can we take from all of this information to aid and improve our own teaching?  First, we must decide how our students will learn.  I believe there is a fundamental battle between passive and active learning, as summed up by Volpe as cited in Michael (2006, p. 159).

       “Public understanding of science is appalling.  The major contributor to society’s stunning ignorance of science has been our own educational system.  The inability of students to appreciate the scope, meaning, and limitations of science reflects our conventional lecture-oriented curriculum with its emphasis on passive learning.  The student’s traditional role is that of a passive note-taker and regurgitator of factual information.  What is urgently needed is an educational program in which students become interested in actively knowing, rather than passively believing.”

       Physics teaching has traditionally consisted of a “sage on the stage” style classroom where students are left to memorize as much as possible of what they hear and read, then solving problems with numbers to get the “answer.”  Laboratory work might consist of following step by step instructions to verify that the material taught in class is correct.  Almost 30 years ago, Volpe recognized a change was needed; a change away from traditional teacher-centered lectures towards students becoming more active in their own learning.

Engaging Students in their Learning:  Lighting the Way

How can teachers create an environment where students are more active in their own learning?  I believe we must lift our students above the role of passive “regurgitator” and allow them to become scientists, a philosophy known as active learning.  Michael offers us this definition from the Greenwood Dictionary of Education (Michael, 2006, p. 160)

“Active Learning:  …The process of keeping students mentally, and often physically, active in their learning through activities that involve them in gathering information, thinking, and problem solving.”

An active learning environment in the classroom turns our students into scientists.  Students are asked to gather information, think and solve problems – in short, to construct working models based on data they collect.  Constructing meaning requires the activation of students’ prior knowledge and a thoughtful extension of to apply prior knowledge to new circumstances.  Michael praises constructivism as a link to prior knowledge.  “Learners construct meaning from the old information and models that they have… and the new information they acquire, and they do so by linking the new information to that which they already know” (Michael, 2006, p. 160).

Evidence for Active Learning

Why should we bring constructivism and active learning into our classrooms?  Where is the evidence that active learning works better than traditional teaching methods?  Using, the Force Concept Inventory (FCI), a valuable assessment tool for the classroom teacher, Richard Hake performed a comparison of learning outcomes from 14 traditional courses (2084 students) and 48 courses using “interactive-engagement” (active learning) techniques (4458 students).  The results showed students in the interactive-engagement courses outperformed students in the traditional courses on the FCI assessment by 2 standard deviations.  \*\*\*\*\*\*\*\*\*\*

In another side by side comparison, Burrowes compared learning outcomes in two sections of the same course taught by the same teacher.  One section was taught in the traditional teacher-centered manner, whereas the other section was taught in a manner that was based on constructivist ideas.  The results of this experiment were striking: the mean exam scores of the experimental group were significantly higher than those of the control group, and students in the experimental group did better on questions that specifically tested their ability to ‘think like a scientist.’”

Our students will benefit from constructing meaning in an active learning environment.\*\*\*\*\*\*\*\*\*\*\*

Applying Active Learning

If we expect our students to use knowledge to solve any kid of problem, we must provide them with opportunities to practice needed skills and receive feedback about their performance (Michael, 2006, p. 161).  I believe this is best accomplished by restructuring our class-time to provide more laboratory opportunities.  Certainly, some topics lend themselves more readily to an active learning approach.  Direct current electricity is a subject rich in the opportunity for reasoning, for the development of models and theories, for the design of crucial experiments, and for free exploration.  “If the students are to realize the benefits of this opportunity, they must be left to their own devices much of the time” (Evans, 1978, p. 16).  However, the majority of students require guidance into a series of investigations by being supplied with some initial suggestions and leading questions (not cookbook instructions that destroy all the inquiry) (Arons, 1997,

p. 199).  McDermott and Shaffer identify three general categories of students’ difficulty with regards to DC circuits; (McDermott & Shaffer, 1992, p. 995).

“an inability to apply formal concepts to an electric circuit”

“an inability to use and interpret formal representations of an electric circuit”

“an inability to reason qualitatively about the behavior of an electric circuit”

The next section of this paper will describe an activity I use in class to provide a guided opportunity for students to use prior knowledge and apply formal concepts to an electric circuit, as well as reason qualitatively about the behavior of electric circuits by examining evidence to construct a working theory.  There is a heavy emphasis on active learning techniques.

Nature of Science with a 3-Way Bulb

Day 1

Many articles have been written detailing series of activities to introduce electric current and circuits.  Teaching Electricity with Batteries and Bulbs (Evans, 1978) outlines detailed activities involving various arrangements of batteries, bulbs and wire.  “As elementary as these tasks may seem, they are essential.  Most of the students have no idea of the way the carious wires inside a light bulb are connected.  Lacking this understanding, how secure can they be in their understanding of ‘circuit’?”

I do a 40 minute battery and bulb activity on day 1 as follows:

1.      Give the students a worksheet with 10 hypothetical setups\*\*\* involving a battery, bulb, and 1 or 2 wires.  I ask students to predict which of the 10 setups will light the bulb and which will not.  They are to write yes or no on the top of each box.  I give them 3-5 minutes for this task.

2.      I then ask them to count the total number of ‘yeses’ and write that number in the upper right corner of the sheet.  As I wander around the room, I can quickly see that most papers have the wrong number in the upper corner.  Typically 1-3 out of 20 or more students correctly predict that only 2 of the setups will work.

3.      I then allow the students 5 minutes to discuss their choices with a partner and check for agreement on yes or no and try to explain/convince the other person if there is disagreement.  I listen carefully to their explanations to each other to get an idea of where they are starting out.

4.      Now give the students a battery, bulb, and 2 wires of 6-8” in length.  It is best to use relatively new alkaline batteries.  Some of the 10 setups are short circuits and will get warm to the touch.  This is important for students to make note of for later discussion.  I do warn them that some of the setups might get hot and be careful not to burn themselves.  I allow about 10 minutes of experimentation, and instruct students to circle the setups that actually work.  This allows me to wander around the room and verify each group is correct in their findings.

5.      I then ask students to write a sentence or two outlining what conditions are necessary for the bulb to light.  Most students indicate something to the effect of both sides of the battery must be touched and the side and bottom of the bulb must be touched.

6.      Next, ask students what the inside of the bulb must look like behind the threads.  Have them predict and draw their ideas on the blank light bulb picture.\*\*\* I then give them a minute or two to discuss with their partner while I pass around clear full size bulbs that have been specially prepared so as to be able to clearly see inside by grinding away some of the metal threaded area.  The goal is for students to see one wire connects to the side (threads) of the bulb and one wire connects to the tip (base).  I close the first day having students draw a complete circuit including a battery, wires, and bulb.\*\*\*

Day 2

1.      Introduction – How do three-way bulbs work?

a.      Begin lesson with a three-way lamp in the front of the room.  Demonstrate the 4 possibilities: off, low, medium, high.

b.      Challenge students to form a hypothesis about how the 3-way bulb is wired inside without making any more observations.  This is a good point for a think-pair-share.  Allow 2-3 minutes for students to form a hypothesis on their own.  Then place them in groups of two or three and allow an additional 5-10 minutes to compare hypothesis.  Instruct the students that they will soon design experiments to test their hypothesis.

2.      Discuss “rules” of the challenge.

a.      Similar to real life, they will be on a budget.  Each group of two to three students will receive $5000 to experiment with and a list of costs associated with various experiments.

b.      Students must design experiments (within their budget) that serve to prove or disprove elements of their hypothesis.

c.      Students can not break open a three-way bulb.  Destructive experiments are not allowed.  I either tell them that in the “real world” some experiments are either too expensive to conduct within budget or simply not possible with current technology.  Breaking open the bulb fits into this category.

d.      Students can not look up information specific to three-way bulbs in print or on the internet.

e.      Students can earn money back by writing their experimental observations down and submitting to Electrician’s Digest, a fictional scholarly journal within the classroom for sharing of information amongst the groups.

3.      Ask the students what experiments they could perform to test their hypothesis.

a.      Encourage testable hypothesis.

b.      Students must construct a written hypothesis.  Drawings or diagrams are encouraged.

c.      At this stage, I emphasize to students that science is a creative endeavor\*\*Nature of Science

(Excerpted from Physics of Everyday Thinking, Chapter 4) \*, and that constructing models and explanations about phenomena in nature requires human creativity and imagination.  These models can then be tested and evaluated based on experimental evidence.

d.      Students should design specific experiments to test various elements of their hypothesis.

4.      Students perform experiments to test hypothesis.

a.      When students have designed an experiment and are ready to perform it, deduct an appropriate amount from their budget.

b.      Example “costs” are listed in table 1.

c.      If students desire to do experiments outside the realm of experiments discussed in the table, use your judgment accordingly.  My rule of thumb was that experiments based on observation are cheaper than experiments that require action or energy.

5.      Students accept or reject original hypothesis based on experimental evidence or research through Electricians Digest.

6.      Ultimately, the lesson culminates in a white-board session where students share their findings with the class.  During presentations, others can comment with similar findings, concerns, or divergent ideas.  My goal is always to encourage student discourse and essentially hide in the background.

Instructor Notes

In my experience, students often generate better solutions to problems when they work cooperatively with 1 or 2 other students than when they work alone.  For this reason, I conduct the three-way bulb activity in groups of 2 or 3 students.  This allows for good conversation within the group and a shared strategy in solving the puzzle.  Furthermore, Michael cites, “meaningful learning is facilitated by articulating explanations, whether to one’s self, peers or teachers” (Michael, 2006, p. 162).  To this end, I recommend having students whiteboard their final solution to the three-way bulb investigation as an evaluative assessment of their learning.  Whiteboards can be graded as necessary, but the important thing is for the students to practice sharing their findings with the community (class).