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A Penny Saved is a Penny Learned!

Daniel Bergman
Iowa State University

A Penny SAVED is a Penny LEARNED

by **Daniel Bergman**

ABSTRACT: This article discusses modifying a specific activity so that it promotes scientific inquiry, cooperative learning, accurate and explicit nature of science understanding, and appropriate assessment. It features a brief description of the original "cookbook" activity and a subsequent adaptation to create an inquiry-based lesson. The activity uses ordinary pennies to teach fundamental concepts such as density and indirect measurements. Extension activities for chemistry students could feature chemical reactions and metal activities. *This article promotes National Science Education Content Standards A, B, and G, and Iowa Teaching Standards 1, 2, 3, 4, 6, and 8.*

"Penny for your thoughts?"

This question sums up my dialogue with other educators during my early years of teaching. Like many novice teachers, I was desperate for ideas. I became a beggar, borrower, and stealer. I quickly learned that finding science activities is not difficult. The challenge, rather, is locating good activities. By "good," I am referring to activities that reflect and promote how people learn, the National Science Education Standards, and my goals for students (such as thorough content understanding, critical thinking, communication, collaboration, an accurate understanding of the nature of science, etc.). A growing practice among science education leaders is to revise activities to more closely match their goals (Clark, Clough, & Berg, 2000; Clough & Clark, 1994a). Teachers can modify lessons and their behaviors to promote true learning and understanding (Clough & Clark, 1994b; Shiland, 1997). Standard step-by-step labs can become inquiry-based investigations. Teachers do not need to reinvent the wheel. All it takes is some fine-tuning.

Through experience and education, I have learned that with minimal time and effort, I can indeed transform standard "cookbook" activities into not just good, but marvelous science lessons. I do not claim the following revised lesson to be spectacular or world-shattering. Still, when compared with its original inception, the modified version is certainly a much more valuable resource.

The Original "Cookbook" Lab - a Recession in Thinking

Before discussing the modified lesson, I would like to share a condensed version of the original activity (Figure 1). This earlier draft involved the students working in pairs from a worksheet. Keep in mind that the original lesson format is *not* recommended!

The Modified Lesson - Mind Inflation

The modified version is applicable in physical science, chemistry, or perhaps another course depending on the extent and direction taken. Content addressed could include mass, volume, density, measurements (direct and indirect), chemical reactions, metal activity series, acids, qualitative analysis, and alloys, to name a few. The general lesson objective is for students to investigate and develop ways to examine the contents of a penny. Materials available include those listed in the original form, as well as any other materials students rationalize to use in their investigation. There is no "worksheet" for the students to follow. Instead, I ask the students to keep a journal of all the decisions they make, all the procedures and trials they attempt, all of the follow-up attempts and corrections to their work. This will become important later.

I begin the activity by giving a penny to each student. The coins constitute a variety of years and relative cleanliness. The students' initial task is to examine the pennies and record their observations. After a few minutes, the students share and list what they have observed. If necessary, the teacher can guide the discussion by asking questions such as the following:

"*What differences do you notice*?"

"*What patterns can you make*?"

"*Why might there be a difference in types of pennies*?"

"*How might the year of the penny affect its characteristics*?"

Through this focused examination, the students will eventually notice that the change in color seems to occur near the year 1982. Pennies before 1982 are darker, duller brown and heavier. Pennies after 1982 have a lighter color, are more lustrous, and weigh less. Pennies from the year 1982 (be sure to include a few of these) may consist of both types.

Ultimately, the teacher can ask the students how they might determine if and how the pennies are truly different. One stipulation is that students cannot destroy their pennies by cutting or filing them. The students discuss ideas in small groups and then share their thoughts with the class. Another list goes on the board. One action

Density Lab - Pennies

Opening Questions: -Are all pennies the same?
-What can density tell you about the composition of pennies?

Materials:
10 pennies made before 1982 — mass scale — water — paper towels
10 pennies made after 1982 — calculator — 100-mL graduated cylinder

Review:
1. (1 pt) Write the formula for density in the space to the right:
2. (1½ pts) Then label what each symbol or variable means.
3. (1½ pts) Finally, indicate the units for each variable.

Objective:
Your mission is to find the density of two types of pennies. In order to find density, you must first measure two things: mass and volume.

Mass:
Finding mass is the simple step. Use an electronic scale to determine the mass (in grams) of both samples. Each sample contains 10 pennies. Repeat your measurements two more times. (Both penny samples will be measured a total of three times.)
-Average the results of the three trials to obtain the average mass of the 10-penny samples.
-Complete the mass data in the data table below (Don't forget Sig Figs!):

Volume:
Finding volume is more involved. You and your partner will create your own method to easily find the volumes of the samples **using the materials given**. Discuss and design your plan of action.

4. Describe your method in the space below, then check this with your teacher before you proceed. ***(Don't forget to factor in Sig Figs when you take measurements!!!)***

5. (2 pts) **Data Table:**

Pre-1982			Post-1982		
Trial	Mass (g)	Volume (mL)	Trial	Mass (g)	Volume (mL)
1			1		
2			2		
3			3		
Average			Average		

6. (4 pts) Using the average volume and average mass of the two sets of pennies, determine the average density of each set. ***Show your work below and include units in your answer (Don't forget Sig Figs!):***
a) Density of Pre-1982 Penny: _________ b) Density of Post-1982 Penny: _________

Analysis/Conclusions:
7. (1 pt) Why did you measure the penny samples three times instead of just once each?
8. (1 pt) Why did you use 10-penny samples rather than just one penny of each type?
9. (2 pts) Examine the procedures in this lab and then answer: What are two possible sources of error in this lab?
10. (2 pts) Using your experimental data, a resource such as your book, and your own reasoning skills, predict the **primary element** each type of penny contains: a) Pre-1982 _______ b) Post-1982 _______

Figure 1. The original, unmodified Penny activity with procedures, graphs, and questions given to students.

plan students commonly suggest is weighing or massing the pennies. The teacher provides students with mass balances or scales. At some point, there should be a class discussion on ways to improve results multiple samples, comparing values with other groups, finding the average mass of pennies, etc. For instance, the teacher might ask, "*How can we be confident that our measurements are accurate*?"

Once students have measured penny samples and shared observations, the teacher can direct the conversation back to the actual composition of the pennies. The teacher could ask, "*How might we compare pennies beyond mass differences*?" "*How could we determine what materials make up these different types of pennies*?" These are questions the students can discuss in smaller groups, develop ideas, and share with the class.

Students may not arrive at a plausible, accurate method to study the pennies. The class may get "stuck." Teachers should welcome frustration as a sign of intent investigation. They can then mention to the class that sometimes when scientists have difficulties, they research into past accounts to see how other people have investigated and solved problems. The teacher can refer the students to the historical account of Archimedes, who had to verify a gold crown's purity. Only the problem is discussed, not the answer. The students' next step is to research about Archimedes and how he solved his task.

Depending on the timing of the class, this could be an appropriate point to end the first day. Between now and the next class period, the students can do their research. It is important to NOT simply give printed resources or Web sites to the students. They can do the research whether during class or outside.

A conversation about Archimedes' work introduces the concept of density. The students may have prior knowledge of density that different materials have different amounts of mass per volume. Reflecting on Archimedes' use of water displacement, student groups can discuss methods for finding volume. They should then develop a procedure to determine the density of pennies. In turn, the students use this information to identify the materials in different pennies.

As students work on their investigations and calculations, the teacher can offer resources (*CRC Handbook*, *Merck Index*) that list the densities of various materials. The students use the information and their experimental results to predict the primary element in each type of penny. An important question to ask students is "How can you increase your confidence in your ideas?" Students may find that their results do not agree with standard measurements accepted by the scientific community. For instance, the density value they determine experimentally may be closest to a gas, which they know is not possible. The teacher can ask the class how they could address such issues (redo their measurements, check calculations, check with other groups, look for other resources).

At the end of the lesson (usually one or two days later), each student group turns in a report of their procedures, decisions, calculations and results and analysis. This report is separate from their journals kept throughout the entire lab. The groups write up an edited, "cleaned up" report that presents the necessary information. Afterwards, the teacher can ask students how they decided on what contents to include in their final report. This is a key opportunity to address an important nature of science (NOS) issue: how scientists do their work privately and how they report it publicly.

Assessment of the final report focuses on the students' rationale for their decisions. There is an emphasis on the students' understanding, not simply their answers. With regard to individual accountability, the teacher could ask students to write a short summary of each group member's contributions. Assessment also occurs throughout the lesson. At different points in time, the teacher should ask questions such as those listed in Text Box 1. Ensuing conversations engage students in continual thinking. This dialogue also helps the teacher assess students' understandings.

There are numerous opportunities for extensions of this lesson. The teacher would choose the direction of learning depending on developmental, safety, and content suitability. For example, this activity could lead into learning about chemical reactions and metal activity. The “hollow penny” is a common lab that uses hydrochloric acid to dissolve zinc from notched pennies. Students could determine the percent masses of copper and zinc in pennies of different years. The key is for the teacher to use the lesson and potential extensions where they work best.

Text Box 1. Sample Assessment Questions

1. Why do you take multiple measurements?
2. Why use multiple pennies instead of just one?
3. To what extent is this like what scientists do?
4. How can you be sure of your conclusions?
5. How might you reduce a chance for error?
6. How can we determine the materials in a 1982 penny?
7. How else could we investigate the contents of a penny?
8. Why do you suppose they changed the materials of a penny in 1982? Who decided to do this? What could we do to find out?

The Mental Exchange - “Decookbooking” Science

I made extensive changes to this activity and its original format. The paragraphs below address the reasoning behind these changes. In particular, I will focus on how the modifications and teacher's role during the activity reflect and promote multiple goals for students, how people learn, and the National Science Education Standards, including the nature of science (NOS). This discussion is intended to assist teachers as they strive to modify cookbook lessons and engage students in inquiry.

Goals for Students

Unlike the original activity (which supports surface content knowledge, number crunching, problem “following,” and has little connection to application) the modified version promotes a variety of student goals. Most notably, I chose to not use a worksheet with a data table and step-by-step calculations. Bypassing the worksheet helps avoid “telling” the students exactly what steps to follow and what decisions to make. The students must rationalize their way through the problem, not simply follow directions.

The students also develop cooperative skills by working together to approach the various tasks. They must decide how to collaborate and share their ideas. The teacher plays an important role in establishing procedures and expectations for cooperative work. Students do not simply copy each other's ideas. The teacher promotes discussion and sharing of ideas, looking at the pros and cons of various decisions. The teacher interacts with students in groups and as individuals to engage their thinking and assess their understanding.

How People Learn

The modified lesson begins with students examining pennies. It is important to have concrete experiences early; the students can reflect on them as they investigate the abstract quantitative values. There is a connection to students' prior knowledge. Even with the national tendency of inflation, the penny is a perennial resident of students' pockets, purses, sofa cushions, and coin jars. Seeing pennies everyday will remind students of this activity, and they will likely share what they learned with others including their parents.

The students share their observations of the pennies. This helps the teacher assess their initial understanding and gets all ideas out in the open. Lists on the board encourage students to view and examine their peers' ideas. Students share their thoughts and use a language common among their peers that the teacher may not possess. Furthermore, students may have multiple ideas for solving a problem. The modified lesson includes an application of the concepts. Students will learn how they can use measurements (direct and indirect) to investigate and analyze ways to approach challenges. They also can research economic conditions that impacted decisions about the penny's composition.

The teacher will want to explicitly address and model safety issues. Students will need to share their potential lab procedures to the teacher before trying them. Safety and procedural areas can still be extremely cognitive endeavors. This is done by asking students why they think these requirements are in place. The teacher's role is to consistently maintain the lesson in the cognitive realm. Through observing, asking questions and listening, the teacher engages the students in thinking and self-evaluating. Otherwise, the lesson could easily slip into thoughtless physical activity and bland number-crunching.

National Science Education Standards

Many goals reflected and developed in the modified lesson align with the NSES content standards for grades 9-12 (National Research Council, 1996). The students will enhance their understanding of science as inquiry. This lesson promotes the standard both through practicing abilities necessary to do inquiry communication, collaboration, critical thinking, etc. as well as developing an understanding about the inquiry process. With regard to the physical science standard, students learn and apply knowledge about structure and properties of matter. Unifying concepts and processes promoted include measurement and evidence. Students actively evaluate and analyze data from their quantitative measurements.

The modified lesson addresses the nature of science (NOS) standard in many ways. The teacher does not simply tell students if they are right or wrong. Students must rely on their collaboration, research and consensus reaching to establish accurate ideas. The students learn about historical perspectives through research on Archimedes. They can reflect on Archimedes' title as “philosopher.” Science was once known as “natural philosophy” an immensely human-ingrained endeavor. Students examine the creative component in science. They consider its connections to social and historical events. Through their journal and report writing, students can reflect how published science reports do not portray the “messy” aspects of private science. There is not a single “scientific method” that all scientists use to solve their problems. Each situation is unique. The teacher must address these NOS issues explicitly through posing questions and encouraging discussion. The students will not arrive at these conclusions by themselves.

The Priceless Teacher

In 2000, Lawrence Baines and Gregory Stanley wrote an article entitled “We Want to See the Teacher.” The authors, reacting to the current emphasis on student-centered instruction, clamor for educators to recognize the key role teachers play in a child's education. Focusing on students' and their learning is essential. However, we must remember that a teacher's role is crucial in a student-centered classroom. If depositing information into students' brains is not the answer, what does a teacher do? What is the teacher's role in a classroom?

Though often overlooked, the teacher's classroom behaviors are crucial for effective instruction. In addition to the actions specifically addressed earlier, the following behaviors are vital for success: open-ended questions; appropriate wait-time before and after student responses; warm and welcoming facial expressions and body actions; movement around the entire classroom; sincere listening and intent observing of student coments and actions; symmetrical responding (not rejecting or giving general praise); and including students on decisions and leading the class (Brophy, 1981; Penick, Crow, & Bonnstetter, 1996; Rowe, 1986).

There is no such thing as a “teacher-proof” curriculum. In fact, a more sought after commodity is a population of “curriculum-proof” teachers. Such teachers refuse to blindly follow stale and scripted science activities. Instead, these good (i.e.: marvelous) teachers locate activities accurately based on how people learn. They implement lessons that promote goals for students beyond simple content memorization. Furthermore, curriculum proof teachers you and I can actively examine and modify activities in order to create authentic learning experiences. This penny activity is an example. Lesson modification is possible. Do it today!

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Daniel Bergman is a Ph.D. Graduate Student at Iowa State University, and had previously taught Chemistry and Physics for five years at Aurora High School in Aurora, NE. Daniel’s last published article, *Share the Science!*, appeared in the May 2004 edition of *The Science Teacher*.