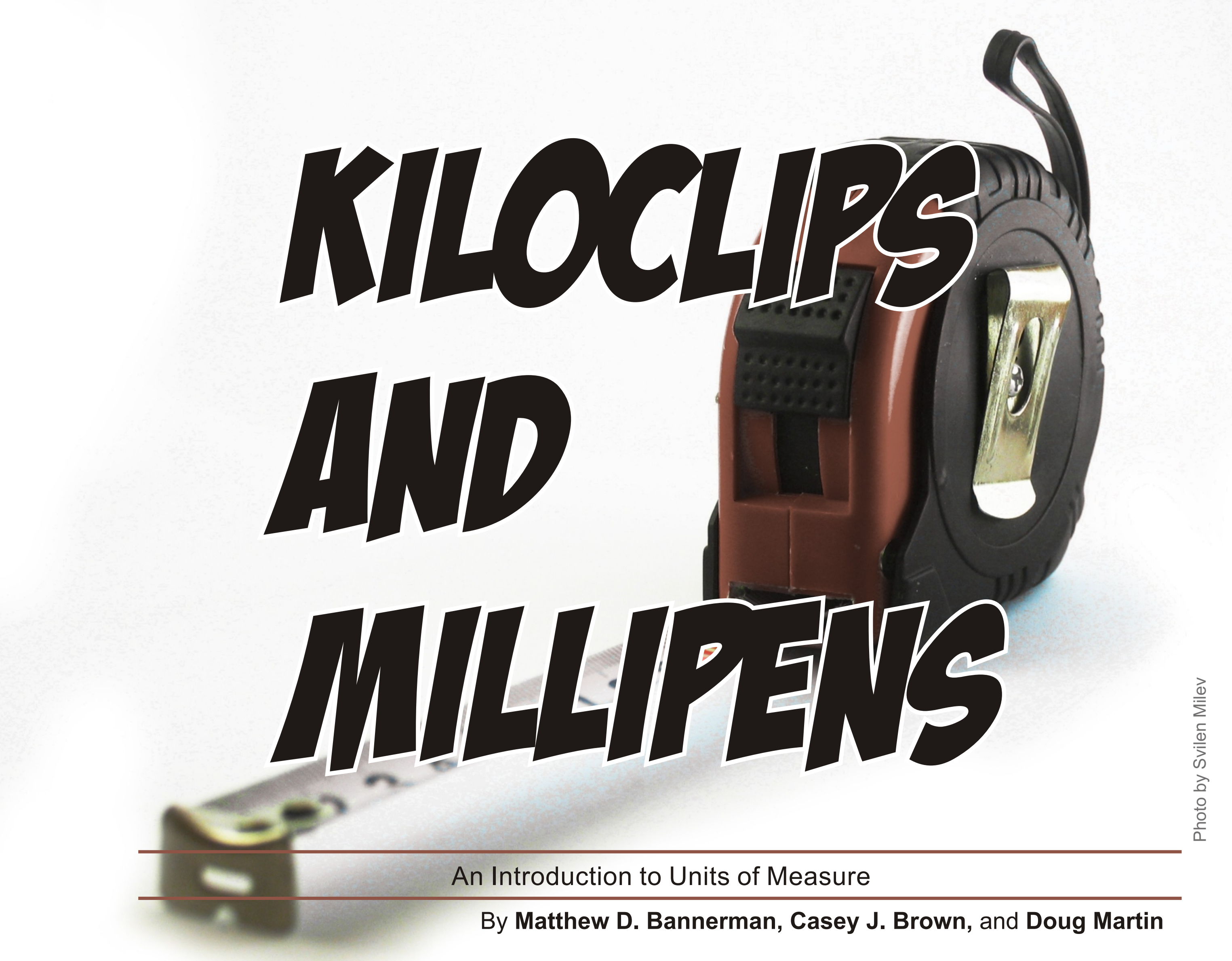

Photo by Svilen Milev

KILOCLIPS AND MILLIPENS

An Introduction to Units of Measure

By **Matthew D. Bannerman, Casey J. Brown,** and **Doug Martin**

ABSTRACT: This article presents a physical science activity for introducing units of measure and the role of human beings in deciding units of measure and their standards. These important science ideas are introduced through inquiry, and in a way that makes this activity appropriate for the beginning of the school year. The manner that this activity is done promotes mental engagement, collaboration, and a deeper understanding of the targeted concepts. In doing so, it helps set expectations for the entire course that students will be actively engaged in learning. The activity uses common objects to serve as standards for mass and has students build their own simple balances to teach mass as a property of matter that should later be contrasted with weight. *This activity promotes National Science Education Content Standards A, B, E, F, and G, and Iowa Teaching Standards 1, 2, 3, and 5.*

Physical science courses traditionally begin by introducing properties of matter and units of measurement. Unfortunately, measurement is often not addressed beyond memorization of units, and little if any reasoning or history behind those units is addressed. Thus, students are not engaged in understanding the significance of units of measure and how human beings have worked, and at times struggled, to develop a coherent system of measurement units. Understanding the arbitrary nature of measurement and units introduces a profound nature of science idea that sets the basis for exploring how science works. Having students work through some of these ideas will help them see science as understandable and something in which they can personally participate.

An important role of teachers is assessing and responding to the developmental and educational level of their students. This activity is designed for students ranging from middle to high school, with appropriate alterations made as determined by the individual teacher. Further, we have attempted to place this activity in an intermediate position between cookbook type activities – those that reduce student thinking by providing an interpretation of conclusions at the beginning of the activity (Clough & Clark, 1994) – and open inquiry that more closely mirrors authentic science. As Clark, Clough, and Berg (2000) state,

> In rethinking laboratory activities, too often a false dichotomy is presented to teachers that students must either passively follow a cookbook laboratory procedure or, at the other extreme, investigate a question of their own choosing. These extremes miss the large and fertile middle ground that is typically more pedagogically sound than either end of the continuum.

While recognizing that science is an inquiry based subject and should be both taught and learned according to the structure of the discipline (AAAS, 1990; Watson & Konicek, 1990), some subtle proscriptive action by the teacher (primarily in the form of questions) is almost always required to assess and respond to students' ability and willingness to participate in inquiry-oriented activities. Thus, the activity functions as an introduction to the inquiry approach (an initial step in setting the stage for a course with a substantial inquiry orientation) and offers a meaningful inquiry experience of its own that challenges students to synthesize new ideas and understandings regarding measurement and agreed upon units.

Setting the Stage

Mass is a property of matter independent from force interaction, although we perceive it primarily through force interactions (e.g. weight). This activity focuses students' attention on creating a system of measurement to compare the relative amount of 'stuff' in objects, and leaves for later explicit instruction regarding mass versus weight. During this activity, students should not be told precisely what materials to use. Rather, a general collection of items in adequate supply should be available. No working balances should be included, since one objective of the activity is that students will come to understand the need for, and build, a balance. However, having a broken balance in sight may help spark student thinking.

At least three materials that students might use as benchmarks or “standards” for comparing the relative amount of stuff in different objects should be available in adequate supply. Example items that may serve as standards include different types of pens/pencils, paperclips and erasers. Also have available materials for building makeshift balances (e.g. wire coat hangers, pushpins, rulers with center holes, small plastic cups and/or lids to serve as balance pans, and string). These materials should be visible to students to trigger ideas, but should not be presented as required for the activity. To help in this regard, also set out reasonable items that you do not anticipate students will use. These additional materials will force students to think about what materials they need, what they don't need, and may result in their using unanticipated materials in very imaginative and clever ways! This strategy is important for teaching students that, like scientists, they must consider a problem and decide how to solve it.

The materials required for this activity are common and safe if used appropriately. However, since students will design and build their own simple mechanisms, safety issues may arise. As with all inquiry activities, students should propose ideas to the teacher and receive permission to proceed. Teachers should always be on the alert, walking around observing what students do and say. When a group's proposal or student action is questionable, please refer to the NSTA minimum safety guidelines available at (http://www.nsta.org/pdfs/440.pdf), your school's policies, and your own professional judgment.

Ensuring Success

This activity is best situated at the start of a physical science course. It typically requires two days, but may progress into a third day if students struggle with the challenges that the activity presents. Students should work in pairs both for the initial questions and activity. Groups of three create management problems as one student will sometimes do the work alone while the other two are off-task. In groups of two, students are more likely to work together to both mentally and physically solve the problems that arise. Small group cooperation in both exploration and explanation maximizes the number of students working at the higher cognitive levels (Saunders, 1992).

Effective teachers establish high, yet reasonable, standards for their students. For desired learning to occur, students must be mentally engaged (Saunders, 1992). High-quality teacher questioning is essential for creating and promoting the mental engagement that helps students make desired connections (Penick, Crow, & Bonnstetter, 1996; Elstgeest, 1985). Because students must think and make decisions rather than mindlessly follow directions, the success of this activity is largely determined by how the teacher uses questions to generate ideas and make desired links.

Throughout the activity we provide examples of the kinds of questions we ask, but effective lessons are not scripted. Creating a student-centered environment means seriously listening to and playing off what students say. The teacher questions and student responses we provide are representative of the activity's general flow. Like all lessons where students' thinking influences instructional decisions, teachers must be prepared to work with students' responses.

When students are reluctant to respond to questions despite the teacher's use of encouraging non-verbal behaviors and appropriate wait-time (Rowe, 1986), don't let students off the hook! Implement a think-pair-share strategy and have pairs write their ideas on white boards. Then move back to the whole group sharing. In group brainstorming sessions, students' answers should be acknowledged and placed on the board. This is important for showing students that their ideas matter (Appleton, 1993) and encouraging further interaction.

Additional questions beyond those presented here will likely be required. For example, if students do not offer "heaviness" to the initial question below, ask another appropriate question to get students to generate this idea. For instance, a follow-up question might be, "In addition to the space an object occupies, how else could the amount of stuff be conveyed?" We have provided questions along the way to illustrate the general direction of the activity. Not every answer offered by students, correct or incorrect, must be immediately considered or explained. However, students' contributions do convey their conceptions and the teacher can decide the appropriate time to return to those ideas.

Introducing the Activity

We begin this activity by asking, "When you pick up an object, what are some things you can say about that object?" Students' responses typically refer to color, size, shape, weight, heaviness, etc. When students' ideas have been exhausted, we ask, "What do you mean by 'weight' or 'heaviness'?" Students will often be puzzled by this and respond, "How much the object weighs". We follow this common response by asking, "How can you determine how much something weighs?" Students quickly offer that the object should be placed on a scale. Follow this with, "How can we compare how much 'stuff' there is in different things without using a scale?" and/or "What other tools besides a scale can we use?" These questions often require more think time, so be prepared to use the think-pair-share strategy mentioned above. While students are sharing ideas with their partner, walk around the room listening to students and asking questions where appropriate that help struggling students generate useful ideas. For instance, you might ask, "What kind of equipment often found at playgrounds could be used to determine the relative heaviness of two objects?"

After the ensuing discussion, instruct groups to design a device that can be used to compare the amount of 'stuff' in different objects. Observe and listen to students as they work, and discuss with individual groups their devices and what they need to build them. If necessary, ask students, "What kind of items are you designing your device to compare?" This along with the kind of materials that have previously been made available will influence students to consider how large their device should be. Students may request additional items that you have not made available. Decide whether to make available those requested items or have students bring them to class the next day.

Make certain students share with you their plans and required materials prior to their being given permission to build. This required dialogue is important for ensuring that students express their thinking, and for you to ask questions that promote deeper thinking and reflection. However, do not expect all groups to initially build functional devices that solve the overarching problem. That is OK. If you determine the device is safe, and if it makes sense to the students despite the questions you have raised, then permit them to begin building. Much is learned by first going down an erroneous path.

Students should spend the rest of the class period working on their devices. While some are determining, for example, how many paperclips are in a pen, others will be making comparisons between other objects. Groups working most quickly and finishing early should be requested to develop other comparison schemes. Encourage students to consider the importance of keeping track of what they do by asking questions such as, “How will you remember precisely what you did so that you can share your results with others?” As Day One of the activity comes to an end, tell students to store their materials where instructed and to begin working on their devices immediately upon entering the room the next day.

Driving Home the Fundamental Idea

As students enter the class the following day, remind them to begin immediately and complete their comparisons. When you determine that all groups have completed comparing at least two objects, have then record their results on the board under the following label:

One [insert object] = X [insert second object]

After students have recorded their results for all to see, ask the class, “If a different class did this activity, how do you think their results would compare to yours?” Students' responses likely will include both “The results would be the same” and “The results would be different”. The key is to follow these answers with “What might account for the answers being different or the same?” Students will quickly grasp that results depend on a number of factors including, but not limited to how well the balances worked, the materials being compared, and how precisely whole numbers could represent the comparison.

Now ask students, “So if the many classes working on this same problem represent the world-wide scientific community, what must be done so that we can effectively work together and communicate how much stuff there is in something?” Students clearly understand that some agreed upon unit of measure makes much sense. This may be the time to ask the following question, “What units do we normally use to describe how much stuff there is in something?” Typically, responses include units such as pounds, grams, tons, and kilograms, but units of volume may also be provided.

Now have students work with their partners to answer the following questions:

1. What units does the scientific community currently use for measuring how much 'stuff' there is in something?
2. What units are sometimes used outside the scientific community for measuring how much stuff there is in something?
3. How did these units of measurement arise?
4. What is the importance in having agreed upon units of measure?
5. What are the advantages of the metric system of measurement?
6. What factors account for the very few countries who have yet to move entirely to the metric system?

Time will likely exist the second day of the activity to address these in a whole class setting. However, they can also be completed as homework.

Because students have first experienced the activity and been engaged in discussions during and after that help them make sense of the experience, they are now in a much better position to understand assigned readings. Hence, this is a fine time to introduce reading from your science textbook and/or other sources that address units of measurement and mass. Other reading assignments should address past struggles to develop and standardize units of measurement for mass, length, volume, time, etc. Much information is available on the web, but ascertain the accuracy and reading level before assigning such readings to students. Problems that arise with having more than one system of measurement may be illustrated in a number of ways, one that involves the crash of a $125 million Mars orbiter in 1999. These readings will be far more interesting and well understood by students because of the experiences and discussions that preceded them. They also present an ideal opportunity to address several important issues regarding the nature of science. For instance, these might include the need to create systems of measurement to investigate particular natural phenomena, the importance of both creativity and consensus in science, and the social nature of science.

For more information on the Mars orbiter crash visit
http://www.cnn.com/TECH/space/9909/30/mars.metric.02/

Moving On

Introducing and having students practice with triple beam balances and standard masses is a logical next step and permits students to see that what they developed in the previous activity is the same in principle as the more sophisticated equipment used in science labs. This too helps demystify science and helps students see themselves scientifically functional. Similar activities are also possible for other measurement types – length, volume, etc. to help achieve similar nature of science goals. At an appropriate time, perhaps after beginning a unit on forces, address the difference and relationship between mass and weight (and balances and scales). The understanding of measurement, the nature of science, and positive attitude and skills of inquiry promoted in the activity presented here will pay big dividends the remainder of the school year and beyond.

References

AAAS, (1990). Effective Learning and Teaching. Chapter 13 in Project 2061: Science for All Americans, American Association for the Advancement of science. Available: http://www.project2061.org/publications/sfaa/online/Chap13.htm

Appleton, K. (1993). Using Theory to Guide Practice: Teaching Science From a Constructivist Perspective. *School Science and Mathematics*, 93(5), 269-274.

Bloom's Taxonomy. (On-line). Accessed: 22 June 2008. http://www.biology.lsu.edu/heydrjay/Bloom's%20Taxonomy.gif

Clough, M.P. & Clark, R.L. (1994). Cookbooks and Constructivism: A Better Approach to Laboratory Activities. *The Science Teacher*, 61(2), 34-37.

Elstgeest, J. (1985). The right question at the right time. In W. Harlen, (Ed.), Primary science: Taking the plunge. Oxford: Heinemann Educational.

Penick, J.E., Crow, L.W., & Bonnstetter, R.J. (1996). Questions are the answer: A logical questioning strategy for any topic. *The Science Teacher*, 63(1), 27-29.

Rowe, M. (1986). Wait-Time: Slowing down May Be a Way of Speeding Up. *Journal of Teacher Education*, 37(1), 43-50.

Saunders, W. (1992). The Constructivist Perspective: Implications and Teaching Strategies for Science. *School Science and Mathematics*, 92(3), 136-141.

Watson, B. & Konicek, R. (1990). Teaching For Conceptual Change Confronting Children's Experience. *Phi Delta Kappan*, 71(9), 680-685.

Matthew D. Bannerman teaches biology and physical science at Clarke High School in Osceola. He can be contacted at matthew.bann@gmail.com.
Casey J. Brown is currently studying to earn a M.A.T. degree in Science Education from Iowa State University. His endorsements will include physics, earth science, and physical science. Casey can be contacted at braunsan@hotmail.com .
Doug Martin has over 15 years of science teaching experience, including the past 7 years at Le Mars Community High School. Doug can be reached at dmartin@lemars.k12.ia.us.