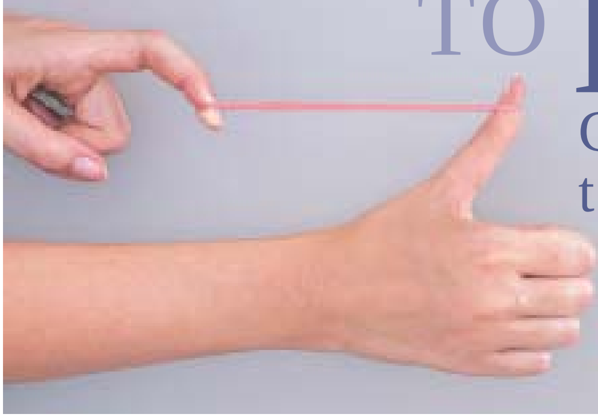
BANDS TO BOOKS

Connecting Literature to Experimental Design



by William P. Bintz and Sara Delano Moore

Science creates a power through its knowledge, a power to do things: You are able to do things after you know something scientifically.
—Richard Feynman

Undoubtedly there is a large body of professional literature that provides philosophical and theoretical support to develop interdisciplinary curricula. But it doesn't always provide examples of interdisciplinary teams putting theory into action in the classroom. Here, we do just that.

The following is an interdisciplinary unit of study on the inquiry process and experimental design that seamlessly integrates math, science, and reading using a rubber band cannon. This unit was conducted over an eight-day period in two sixth-grade classes (one math and one science with each class consisting of approximately 27 students and lasting 45 minutes). We begin by describing a series of interrelated curricular engagements that make up the unit. Throughout, we share samples of student work. Lastly, we describe some lessons learned and discuss both problems and pleasures of creating and implementing an interdisciplinary curriculum at the middle level.

Demonstrating

To get students started, we provided an overview of the interdisciplinary unit and displayed a rubber band cannon. The cannon, which can be built relatively easily, consists of a rectangular base with a quarter-circle arc marked in degrees. The shooting arm is approximately 40 centimeters long on an adjustable hinge and can be set from 0 to 90 degrees in 10-degree increments. The cannon is available for purchase from NASCO (*www.enasco.com*).

We randomly selected six students (one data recorder; two markers/measurers; three shooters) to participate in an initial experience with the cannon. First, we showed students the chart in Figure 1 (written on the whiteboard) and asked them to predict which rubber band (small, medium, or large) will travel the farthest based on the data. The majority of students selected the small rubber band because "it doesn't weigh as much as the other two." Next, we pushed the students' desks against the walls to clear the middle of the room. Shooters and one measurer gathered at one end of the classroom; the other measurer at the other end, approximately five meters away. The recorder was at the whiteboard to record distance data on the chart. Note: All participants must wear safety glasses during this activity.

To highlight the concept of constancy in the demonstration, we asked, "What are some things that we have to keep constant for this to be a good experiment?" Students decided the way they stretch the rubber bands is important, as is how they measure. After several minutes of discussion, the students launched the rubber bands, which were then marked, measured, and recorded on the chart, while the rest of the class observed from behind the shooter. Based on the data, students (except the four students who predicted correctly) noted that their original predictions were incorrect. We asked what really made the difference. As a class we further discussed the variables and the need to test them separately. We used this discussion to transition to the next stage of the unit: to design, conduct, and collect data on their own experiments.

Connecting to literature

We revisited the demonstration with the rubber band cannon and discussed how the distance a rubber band traveled was the dependent variable and size of rubber band, pull-back (force), and angle were independent variables. Next, we started with an oral reading of *Mr. Archimedes' Bath* (Allen 1980) to help

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students make connections between the story and inquiry process, experimental design, and dependent and independent variables. This story takes approximately 5–10 minutes to read aloud. While one copy is sufficient, it is helpful to project the illustrations on a screen, or to provide several copies for students to follow along in small groups.

The story is about a man named Mr. Archimedes and his animal friends. Mr. Archimedes wants to find out why his bathtub overflows with water when he and his friends jump in, even though he doesn't fill it to the top. He suspects different animals are the single reason, but eliminates them one by one. In the end Mr. Archimedes exclaims, "Eureka!" as he finally learns that all of them are responsible for the water rising when they get in and for the water falling when they get out.

This delightful story has many layers of meaning and offers many possible teaching strategies. It can be an introduction to Archimedes, the famous Greek mathematician and scientist who shouted "Eureka, Eureka!" after discovering what has since become known as the first law of hydrostatics (Dunham 1990). It can also be an introduction to the concept of displacement and its relationship to buoyancy. In this case, we used the story to introduce students to the process of formal scientific inquiry.

For example, Mr. Archimedes first asks an inquiry question based on personal interest, curiosity, and observation: *Why does the bathtub overflow when it is not filled up to the top?* Second, he sets up an experiment and systematically observes and records data: *Fills the bathtub with water and measures the depth*. Third, he tests a hypothesis: *One of the animal friends must be causing the water to rise*. Fourth, he controls for variables: *Invites all of his animal friends into the bathtub except Kangaroo*. Fifth, he revises and retests hypotheses: *Invites all of his animal friends into the bathtub except Goat, then all except Wombat*. Finally, Mr. Archimedes creates causal relationships and draws conclusions: *He and his animal friends are causing the water to rise when they all get in the bathtub and fall when they all get out.*

After reading the story, we gave students approximately 10 minutes to write a summary of the story. Next, we distributed an experimental design sheet, which listed the major components of the inquiry process, as it relates to experimental design (Figure 2). We invited students to make connections between *Mr. Archimedes' Bath* and experimental design. Specifically, we asked them to use the story to map how Mr. Archimedes used the inquiry process and experimental design to solve his problem of water overflowing

FIGURE 1 Demonstrating

Shooter #	Size of rubber band	Pull-back (force)	Angle	Distance
#1	Small	10 cm	30 degrees	
#2	Medium	15 cm	20 degrees	
#3	Large	20 cm	40 degrees	

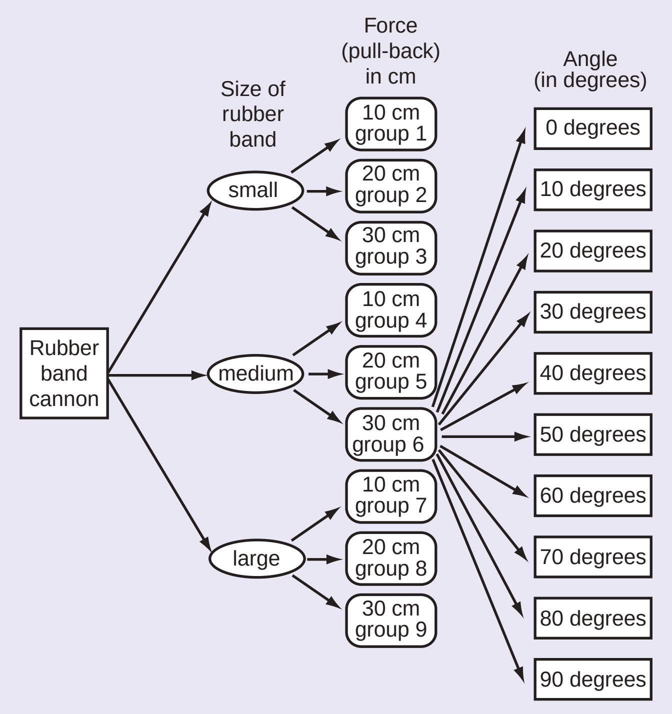
Note: Originally the chart did not specify degrees in the angle column. We asked each of the three "shooters" to select different angles to use.

FIGURE 2 Experimental design sheet for analyzing *Mr. Archimedes' Bath*

After reading *Mr. Archimedes' Bath*, analyze the story and break it down into the following experimental design components. (Sample student breakdown in right column.)

Experimental design	***Mr. Archimedes' Bath***
Title: Give your experiment an appropriate title.	Crouching water, Hidden displacement
Purpose/Question: What is the purpose of your experiment? What do you want to find out?	Why does the water keep rising?
Materials: List all materials that you will use in your experiment.	Water, measuring stick, bathtub, animals, Mr. Archimedes
Variables: Identify your independent variables, dependent variables, and the constants.	
Independent variables:	Animals and Archimedes
Dependent variables:	Water level
Constants:	Depth of water
Hypothesis: What do you think will happen? *If the (independent variable) is (increased/decreased), then the (dependent variable) will (increase/decrease).*	
Procedure: List the step-by-step plan that you will follow.	
Findings: Collect your data, record your results, and represent them in charts, graphs, scatter plots, etc.	
Conclusion(s): Does your data support your hypothesis? Why?	
Reflection: What would you change if you were doing this experiment again? Is more research or experiments needed? What did you learn from doing this experiment? What other questions have been raised by doing this experiment?	

FIGURE 3 Tree diagram



the bathtub. Students talked in groups for 10–12 minutes. Afterwards, we facilitated a discussion about connections between the book and experimental design.

Organizing

We grouped students into nine groups based on a tree diagram (Figure 3). All nine groups then shot rubber bands at angles ranging from 0–90 degrees, with three groups using small rubber bands, three using medium, and three using large. Students then collected the data.

In groups, students used the tree diagram and the experimental design sheet to develop their own experimental procedure based on assigned independent variables for each group (Figure 4). We used the following prompt to guide their work: "As you design your experiment, think about this. If you took your sheet and gave it to a friend so that she could replicate the experiment, would she know exactly what to do based on what you wrote?" Students worked on their design sheets and submitted them at the end of class.

Collecting and recording data

We headed to the gymnasium to take advantage of the high ceiling to collect data. Students were instructed to stay behind the shooting line or well to the sides of the target zone at all times. A number of adults (teachers in this case, but parent volunteers could help as well) were with the class during this phase of the process to monitor student safety practice. If a gymnasium is not available, quiet hallways, a stage, or a sheltered outdoor area could work. The two key features to a good space are high ceilings and lack of wind. (During the demonstration in class, rubber bands hit the ceiling when launched at angles of 70 degrees or more.)

We set up a total of nine stations at one end of the basketball court. Each station included the following: colored cardstock indicating group number, size of rubber band, and pullback; a rubber band cannon; measuring tape; pencil; a set of five rubber bands (either small, medium, or large); safety glasses (mandatory); and a data collection sheet.

Students used the entire 45-minute period to collaboratively collect and record data. Afterwards, we asked students to share their observations and hypotheses, which resulted in a lively discussion on how weight influences momentum and the relationship between angle and lift.

Analyzing and calculating data

We used poetry to help students think about data analysis, specifically measures of central tendency. The poem we used, "Mean, Median, Mode," is projected on an overhead (Bintz 2004). In this poem one voice is the mean, one the median, and one the mode. We asked three volunteers to read the poem

FIGURE 4 An experimental design sheet prepared by a student group

Title: Rubber band cannons

Purpose/Question: With a small rubber band, what degree angle goes farthest?

Materials: small rubber band, rubber band cannon, tape measure, safety glasses

Variables:
Independent variable: angle
Dependent variable: distance rubber band travels
Constants: small rubber band, 20-cm pull-back, same cannon

Hypothesis: We think that a 40-degree angle will make the rubber band go farthest.

Procedure:
1. Obtain all materials
2. Put cannon in desired spot
3. Adjust to wanted degree angle
4. Take small rubber band and place at 20-cm pull-back
5. Let go and record distance
6. Repeat each angle three times
7. Make sure constants are constant
8. Repeat from step 2 at a different angle

Findings: see attached sheet
Conclusion(s): see reverse
Reflection: see reverse

to the class. Afterwards, we explained that mean, median, and mode are called measures of central tendency and asked students which is the best measure to use on our rubber band cannon data. After some discussion, students agreed it was the mean.

Learning about graphs

We used the book *Tiger Math* (Nagda and Bickel 2000) to help students learn about graphs. This book combines both narrative and expository text. The right side pages of the book tell the story of T.J., an orphaned tiger cub; the left side pages use graphs to illustrate how T.J. grew and developed over time.

We used this book to help students understand a line graph, as well as how to graph their rubber band cannon data on line graphs. After reading the story to the class and pointing out the properties of different graphs, we facilitated a discussion that resulted in a list of characteristics for multiple line graphs.

Then, we formed three sub-groups (according to the size of the rubber band) to create three line graphs. In creating graphs, each of the three groups used the same scales on the *X* and *Y* axis; the same labels for the *X* axis (angle in degrees) and the *Y* axis (distance in centimeters); and the same key for different lines (pink for 10 cm, orange for 20 cm, green for 30 cm). To create the line graphs, each member of the sub-groups assumed one of the following responsibilities: data checker, grapher, plotter, or connector. Afterwards, the sub-groups posted their line graphs on the whiteboard.

Interpreting data

We wanted students to analyze data from the line graphs and use the analysis to take target practice. We taped the three line graphs on a wall in the gymnasium. We also set up three stations in the same place where we had set up the nine stations to collect our original data. We placed each target in the middle of a dark shower curtain (to make the rubber bands more visible), approximately 300 centimeters from the cannon. We then organized students in front of the three line graphs. Then, we gave each student a copy of the Prediction and Outcome sheet and directions (see Figure 5).

Students analyzed data on the three line graphs and used the analysis to record their predictions. Next, students went to one of the three stations to shoot rubber bands and record the outcomes. Students left each rubber band where it landed. After all students shot their rubber bands, we organized the class around one of the shower curtains and asked them to share what they learned from the whole experience. Most students concluded that they had the best control over their shots at a moderate angle (30–50 degrees) and that they could then manipulate both rubber band size and force (pull-back) to get the desired distance on the shot. Students were quite articulate about the fact that when the angle is high (70 or 80 degrees), the rubber band spent much of its energy flying up and didn't go out very far.

FIGURE 5 Prediction and outcome sheet

Look at the three graphs that summarize the data collected on the effects of size, force (pull-back), and angle on the distance a rubber band travels. Your target is set at 300 centimeters from the cannon. In the chart, use the Predictions column to record the settings you will use to shoot your three rubber bands (small, medium, large) at the target. You must also record the reasons why you selected these settings. Afterwards, use the Outcomes column to record the distance your rubber band actually traveled and your thoughts on why it did or did not hit the target.

	Predictions	Outcomes
Small		
Medium		
Large		

Lessons learned

From this experience we learned that literature not only offers students an engaging story but also provides context for students to understand concepts in other disciplines. Scheduling students and dealing with time and space constraints were real problems. The process takes a lot of planning and requires coordination and collaboration with other faculty. However, the biggest hurdle was, and continues to be, the scheduling dilemma—a discipline rather than an interdisciplinary model of scheduling means that teachers have different groupings of students.

We agree, though, that this experience was fun and exciting. It was an engaging way to teach students about experimental design. And as a team, we moved beyond just reading and talking about an interdisciplinary curriculum to actually teaching one! ■

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