Mixing Carefully: "Scientific" Jello Preparation: Instructor Guide

Title:

Mixing Carefully: "Scientific" Jello Preparation

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Discipline:

Physics and Astronomy

Target Audience

Introductory, nonmajors

Keywords

Error propagation, gel, measurements, specific weight

Length of Time/Staging

Four to five weeks, about four hours/week. Three stages.

Abstract

Introductory, nonmajor laboratory courses are perfectly suited to a PBL approach. In these courses, the main objective is to involve students with diverse interests in exploring the scientific

method in a 'practical' laboratory setting. This problem has been used in a freshmen course to explore the concepts of volume and weight while learning how to perform simple measurements and how to treat errors. It is suitable for courses such as 'Conceptual Physics' and 'Armchair Chemistry'. The framework of the problem is the preparation and the discussion of the properties of jello.

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Format of Delivery

Groups of four students, classroom/lab with internet access.

Student Learning Objectives

1. Explore the concepts of volume, specific weight, and the law of mass conservation.
2. Learn how to perform simple measurements and how to treat errors.
3. Use different systems of units.
4. Validate experimentally a theoretical prediction.
5. Discuss qualitatively and quantitatively the properties and the microscopic structure of gels and foams.

Student Resources

Internet, introductory physics and chemistry books.

Instructor Resources

1. Error analysis books/tutorials such as:
    a. Tayor, J.R. (1962). An introduction to error analysis: The study of uncertainties in physical measurements. University Science Book.
    b. Simanek, D.R. Error analysis (Non-calculus). Accessed from: www.lhup.edu/~dsimanek/errors.htm
2. Rulers (at least one for each group)
3. Cups/containers of different shape for measuring (several for each group, better if made of metal/plastic)
4. Containers to prepare and store the jello (freezer boxes work well)
5. Jello ingredients: hot water (need a boiler), gelatin, sugar, flavoring
6. Scales (we used standard lab scales)
7. Barham, P. (2000). The science of cooking. Springer.

Author's Teaching Notes

This PBL activity has been prepared for a freshmen laboratory that complements conceptual physics courses. It doesn't assume any previous physics knowledge and uses a minimum mathematical background (graphing and basic algebra). Groups of four students work on this three stage problem for four to five weeks spending about four hours per week in group activities. The students use mostly the internet, although at times they consult introductory physics and chemistry books available in class or at the library.

The main goal of this problem is to apply a scientific approach to the preparation of jello (the theme of the course was the science of cooking). In doing so the students:

- explore the concepts of volume, specific weight, and the law of mass conservation,
- learn how to perform simple measurements and how to treat errors,
- use different systems of units,
- validate experimentally a theoretical prediction,
- discuss qualitatively and quantitatively the properties and the microscopic structure of gels and foams.

At the beginning of the class, I frame the problem by drawing a concept map that elaborates on the analogy between the scientific method and cooking. This serves as introduction to the course in general and to this problem in particular. Groups are then invited to discuss part one, formulate the learning issues, and organize their work. Students usually have no problem at this stage, though sometimes their visions of making jello "from scratch" reach impractical limits (some thought to bring bones in class to prepare gelatin). Groups are usually surprised when they discover the basic ingredients of jello. Collecting information on the molecular structure of the ingredients is important, since the physical properties of jello will be linked to the microscopic structure during part three. The outcome of the first stage is a report that must include a recipe for jello. The recipes are usually in American Liquid Measures (cups, tablespoons, etc.).

Part two starts with a role game. Students are asked to put themselves in the protagonist's position and to translate the recipe in metric system (international system, SI). After a little research, the groups discover that cooking units measure volume. I usually question them about the meaning of the word "amount" and push them toward the concept of specific weight that will be used later. Containers of different shapes and volumes are provided to the class and discussion is open on the concept of units and measurements. Each group develops strategies to measure the ingredients. Possible strategies are: (1) use of a single container as the unit and proportional doses of the ingredients, (2) conversion of all the cooking units to liters or cm3, (3) use of Coke cans (that are everywhere and are labeled in ounces and deciliters, as students pointed out). One of my goals is to have the students "scientifically" measure the volume. In order to lead them in this direction, I usually deliver a short lecture on measurements, errors in measurements, and error propagation (30-40 minutes). Then I ask the student to calibrate their containers. In general, this is not an easy task for my students. For more skilled groups, it can be set up in a discovery-based approach more consistent with PBL. The expected outcome of stage two is a report defining and comparing systems of units. This must include the definitions of measurement, error, and error propagation. The work and calculations performed to calibrate the containers (measuring their dimensions, averaging, finding the errors, and computing the volumes with error) must be attached.

In part three, the students, armed with the calibrated containers, prepare jello using the measurement strategies they elaborated during part two. In addition, they are asked to monitor the transformation occurring and describe and explain the observation in a report (I ask them to emphasize the microscopic-molecular view). Also, they need to elaborate new learning issues in order to explore the link between volume and weight. I push them to "scientifically" keep track of the errors and estimate the weight of the jello they are preparing. The need for quantitative values of specific weights pushes them to perform additional research. I usually ask them to validate the data by doing their own measurements for the principal ingredients (sugar, water, gelatin powder). This is the point where students should be allowed to use scales. The prediction of the total weight of the jello is an additional outcome as well as the actual measurement using scales. It is natural at this point to lead the student to the concept of mass conservation and verify their prediction (with errors).

$$\rho_s V_s + \rho_w V_w + \rho_g V_g = w_j$$

Often, I also ask the students to measure and to compare the specific weight of jello with the average specific weight of their group. They need to elaborate strategies to measure the volume of their bodies. The comparison shows the similarity between a human body's specific weight and jello's specific weight.

Although student are required to submit learning issues, tables, and reports after each stage, the assessment is performed on a final manuscript that reports on all the information and data collected.

Assessment Strategies

Evaluation of the report. A presentation may work, too.

Solution Notes

Solution is quite open depending on the choices done by the students and how the learning objectives are prioritized.