Weighing and Graphing

Subject Area	Physics, chemistry, or other experimental science.
Age or Grade	Upper middle / elementary high school science class.
Estimated Length	One 45-minute lesson (with possible follow-up later, depending on how quickly the groups progress).
Prerequisite knowledge and skills	Equation for a straight line, linear data-fitting, basic error analysis.
Lesson Goals and New Content	Learn / review linear graphing and data analysis. Understand / review the concepts of precision and accuracy. Understand that experimental data always comes with an error, and learn to consider sources of errors when conducting an experiment. Can be a segue into a discussion on significant figures.
Materials Needed	Container of water (one per group). Empty cup (one per group). Graduated cylinder, needle-less syringe, or other measuring tool (one per group). Graphing paper (one per student). Worksheet w. instructions (one per student). Electronic kitchen scale, precision of 1 g (one total). Analog balance, precision of 0.1 g (one total).
Procedure	**Opener** (~10 min.) Ask the class if they happen to know the density of water. Most will probably know. Tell them that

	today they will get to check that number by measuring it themselves, but they have to choose one of two possible instruments. Introduce them to the two scales. Ideally, choose an analog balance that is slightly inaccurate (has a systematic error), but is more precise than the electronic scale, which should be accurately calibrated. Let the students split into groups of 3-5 students each, and give them a few minutes to decide what instrument to use. **Development** (~25 min.) Distribute the worksheets and let the students work through the task while walking around and helping. Given the time, the groups should be able to start part of the homework on the worksheet as well, which basically walks them through the data analysis. Most groups won't finish, but the remainder of the worksheet is designed to be homework for the following day. **Closure** (~10 min.) Even if all the groups haven't finished all the questions, stop them about five minutes before the end of class. Ask the groups why they chose the instrument they did. In my experience, most students will choose the electronic one, because they think electronic automatically means better. Hear arguments, preferably some for both instruments. (If everybody only likes one, try challenging them by arguing for the other.) Even if the students haven't gotten that far on their

	worksheet, ask which one they think is more precise. Many will confuse it with accuracy, so remind them of the difference. (They should already have seen the difference between accuracy and precision, but students often get the two terms confused.)
Evaluation	The worksheet itself has homework on it, which can serve as an evaluation stage. I would also go over the results with the students to be sure everyone understands the material. In particular, I would touch base with the students after having looked over the homework and revisit the ideas of experimental error.
Extensions	A discussion of good measuring habits naturally follow this lab. (For example, "how do you measure volume accurately?") The lesson can also be a portal to discussing significant digits, and how to present your final data. (For example, "with how many sig. digits did you read off the volume? How many did the scale give you?") Depending on the students' previous understanding of the concepts involved, further discussions of systematic vs. random error and precision vs. accuracy can also follow this lab.