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Reflections

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The Most Important Math for Learning Physical Science

Part I – Histograms: Identifying Patterns in Data

by Bob Stair

(Aside from basic computational skills, there are two important bits of mathematics—histograms and proportionality—that are needed to get the most out of an inquiry-based physical science course such as Introductory Physical Science. *In this article, we address one of these mathematical tools, histograms. A second concept, proportionality, will be addressed in a subsequent article.)*

In 1989, Martin Fleischmann and Stanley Pons announced the discovery of "cold fusion" in an electrolysis experiment involving heavy water. There was a great deal of excitement about what this could mean for future energy production and use, but there was also a problem…the claimed results could not be duplicated by other researchers!

As teachers, we emphasize to our students that experimental results do not achieve acceptance by the scientific community unless, among other things, they are repeatable. Yet even before the advent of educational standards and benchmarks, there was rarely sufficient time in the school year to repeat experiments a sufficient number of times for students to be truly confident of their results.

So how can we be certain of the results obtained from any student experiment if the experiment is performed just once? *IPS* has resolved the requirement for repeatability within the time constraints of the educational setting by having students compile class data. This is often accomplished by creating a class data table that contains information from each lab group.

But raw data and calculated values presented in a table format are often difficult to interpret. For example, consider the question "Does the mass of water and salt remain the same when salt dissolves in water?" Beginning physical science students easily recognize that answering this question involves comparing the total mass of the water and salt before mixing to the total mass after mixing. But what does that comparison mean when different lab groups get different changes in the total mass of the salt and the water? How should the results be interpreted?

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Consider the following data table that resulted from a compilation of student results for Experiment 2.1, The Mass of Dissolved Salt. (Sample experimental data such as this can be found in the *IPS Teacher's Guide and Resource Book*.)

Lab Group	Mass Before Mixing (g)	Mass After Mixing (g)	Change in Mass (g)
1	32.17	32.24	+0.07
2	29.57	29.36	−0.21
3	28.67	28.67	0
4	38.02	38.02	0
5	27.67	27.64	−0.03
6	31.55	31.55	0
7	31.45	31.43	−0.02
8	35.12	35.12	0
9	31.45	31.45	0
10	28.67	28.65	−0.02
11	31.31	31.26	−0.05
12	32.55	32.38	−0.17
13	32.26	32.21	−0.05
14	34.29	34.27	−0.02
15	31.43	31.39	−0.04
16	31.86	31.86	0
17	30.86	30.87	+0.01
18	30.29	30.29	0
19	29.14	29.15	+0.01
20	30.86	30.64	−0.22

Can a pattern be identified from these values that would allow us to answer the experimental question? What would your students see in this table?

Beginning physical science students often see each distinct value as different from all of the others. They usually do not have a fully-formed understanding of whether values are significantly different, and so may consider "−0.02" and "−0.03" to be very different. If this is the case, a review of the results of Experiment 1.8, The Sensitivity of a Balance, may be in order.

Even those students who are aware of the variation in experimental results caused by (among other things) the sensitivity of their balance may have trouble spotting a trend in the data. From the table alone, how would you expect your students to answer the question about the mass of salt and water? Would they be able to identify a pattern in the results? Would they notice that several negative signs appear in the "Change" column and say that the

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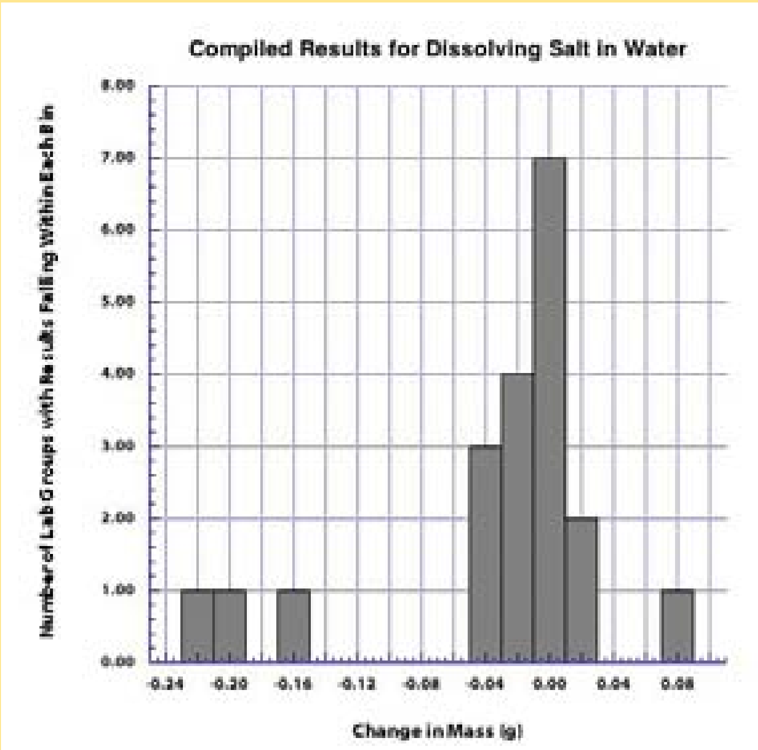
total mass decreases? Would they average all of the changes and, again, conclude that mass is lost? Would they say that there are more "zero changes" than any other value, and so the total mass does not change? Of course, the answer to each of these questions is "yes"! If we can identify each of these possible conclusions, there will almost certainly be a student in your class(es) who will also think of that possibility.



Trends in data are often not obvious when viewing raw data and calculated values in a table. An easier way to identify trends in data makes use of a graphical representation. This is where histograms play a role.

A histogram displays a frequency distribution. It shows how many lab groups obtained results that fall within a certain range, or "bin." By linking the bin size to the sensitivity of our measuring instrument, we can conveniently group the data, eliminating the possibility of insignificant differences being viewed as important.

Consider the histogram at the left. It was constructed from the data provided earlier.

With this histogram, students can more

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How is the *IPS Assessment Package* Different from a Test Bank?

Past editions of the *IPS Assessment Package* have been printed as a book, separate from the student textbook and the *Teacher's Guide and Resource Book*. This book contained two versions of a chapter test for each chapter in the student text, along with lab tests that could be utilized at various times during the school year. The 9th Edition of the *IPS Assessment Package*, however, is provided on a CD rather than as a book. This format allows us to provide five forms of each chapter test, in addition to the lab tests, allowing you to address the problem of "transferance" of information about the test from one class to another.

One thing that the *Assessment Package* is not...it is not a test bank that can be modified by the end user. A great deal of effort has gone into the formulation of the questions on each test to ensure several things:

(1) that the questions match the content and approach taken in *Introductory Physical Science*;

(2) that the questions involve higher-order thinking skills rather than simple recall of knowledge;

(3) that the questions test what they are intended to test;

(4) that there is some diagnostic value to many of the incorrect answer choices, enabling the teacher to plan remediation that addresses the specific needs or misconceptions held by each student.

Public domain test banks rarely test more than knowledge and recall. The *IPS Assessment Package*, on the other hand, contains thoughtful, high-quality, proprietary, copyrighted material designed not just to assign a grade, but to help you address the needs of your students. **For more information, visit www.sci-ips.com/p_ips9_assess.htm, call toll-free (888-501-0957) or contact us by email (tom@sci-ips.com).**

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easily identify the data trend and answer the experimental question than they could by looking at the data table. It is now evident that four of the calculations are "outliers," and that most of the values are clustered around zero change in mass. The experimental question has been answered.

Beyond answering the original question, a histogram can stimulate additional thought during the post-lab discussion. What might be the cause of the large loss of mass seen by three lab groups? What might have happened to result in the large increase in mass reported by one lab group? Why, even within the clustered data, does there appear to be a slight bias toward a loss of mass?

A histogram presents a pictorial image of data patterns—patterns that often are not distinguished from a data table. And it does so while remaining true to the processes of science and accommodating the time constraints of the modern classroom. Truly, the construction and interpretation of histograms qualifies as one of the most important mathematical skills needed by beginning physical science students.

(In the next Reflections... The Most Important Math for Learning Physical Science–Part II, Proportions: Finding Relations Among Variables)

Plan Now for the 2012 *IPS* National Workshops!

In July of 2012, Science Curriculum Inc. will offer three different *IPS* workshops at Colorado School of Mines in Golden, CO. The workshops will cover Chapters 1-6, 7-11, and 12-16, respectively, of the 9th Edition of *IPS*. Although we are still in negotiations with Colorado School of Mines regarding lab use, the tentative dates for the workshops are as follows:

***Introductory Physical Science* – Part 1** (covering Chapters 1–6) July 15–20, 2012

***Introductory Physical Science* – Part 2** (covering Chapters 7–11) July 22–27, 2012

***Introductory Physical Science* – Part 3** (covering Chapters 12–16) July 22–27, 2012

In addition to the content covered in Chapters 1-6 of the 9th Edition of *Introductory Physical Science*, the Part 1 workshop addresses the philosophy of the *IPS* program. Consequently, it is highly recommended that you attend the Part 1 workshop prior to taking either the Part 2 or Part 3 workshops.

In the *IPS* Part 2 workshop, topics covered in Chapters 7-11 of the 9th Edition of *IPS* are addressed. These topics include the atomic model and a new chapter on molecular motion.

The *IPS* Part 3 workshop covers topics often found in the physics portion of physical science standards. Energy, forces, and motion (including Newton's Laws) are addressed.

In each of the *IPS* workshops, participants perform and discuss all student experiments, in addition to discussing classroom strategies, basic concepts, laboratory skills, and safety issues. Reading, reasoning, and student communication are addressed, in addition to the use of software in both student experimentation and the evaluation of student work.

For more information, please feel free to contact Tom, our School Services Coordinator, toll-free (888-501-0957) or by email (tom@sci-ips.com).