

Excelets: A Simple, Rapid Deployment Computational Tool with Visualization and Pedagogical Powers for Middle and High School Teachers

[Scott Sinex](#) and Susan Ragan
[Maryland Virtual High School](#)

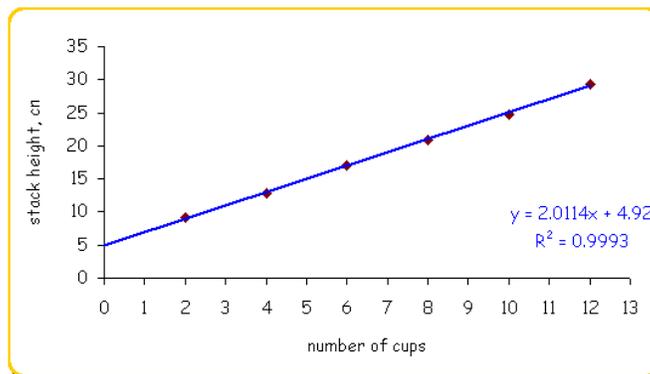
Computational science, using high-performance computers, has become the third pillar of science now joining experimentation and theory. How can computational science be introduced into the middle and high school curriculum? Using spreadsheets, such as Microsoft Excel or Open Office Calc, allow teachers to introduce the basics of mathematical modeling of data and to build simple dynamic and interactive simulations. An engaging pedagogy via discovery learning can be created using off-the-shelf software.

So how do teachers get started in computational thinking? Over the last three years, we have introduced high school and some middle school teachers to mathematical modeling and simulation using Excel through the [Computation and Science for Teachers \(CAST\) workshop](#) held at the Pittsburgh Supercomputing Center and recently as part of the SC 08 Education Program. Teachers are introduced to a simple model via experimentation (collecting data) and a pre-built "just add data" Excelet, an interactive Excel spreadsheet. All of this requires no previous Excel experience. We build a linear model (see screenshot below), analyze it, extend model parameters by simulation, and do some error analysis.

Measuring the Stack Height of Nested Styrofoam Cups - Building a Mathematical Model

Using a centimeter ruler, carefully measure the stacks to the nearest 0.1 cm. Record your data in the yellow cells.

number of cups	stack height
2	9.1
4	12.8
6	17.1
8	20.9
10	24.8
12	29.3



From the best-fit line record the following in the yellow cells:

What is the value of the slope?

2.01

What is the value of the intercept?

4.92

How well does the line fit the data?

R² value

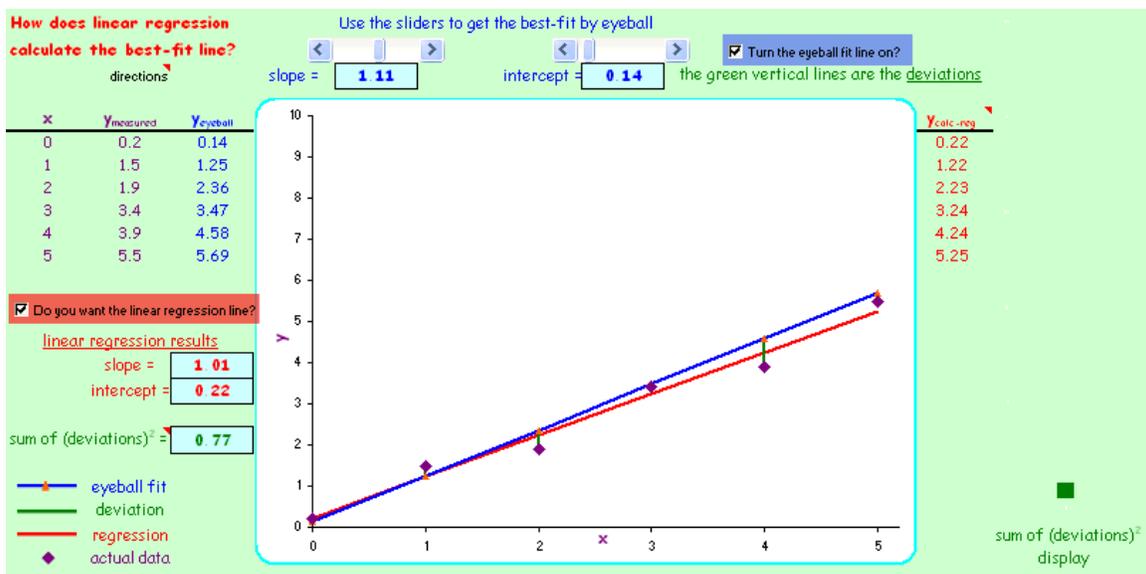
As data are added, the points will plot and a best-fit line and the equation of that line will appear on the graph.

Rewrite the equation in terms of the actual variables measured. answer

Let's explore what the linear equation means.

Let's predict using the equation

From the use of interactive Excel spreadsheets or Excelets and a predict-test-analyze strategy, we drive teachers through the scientific process of mathematical modeling and simulation. Through all of this we maintain the mathematical level at algebraic concepts and some logic statements. Then we go to mathematical modeling of a variety of data sets, usually easy to collect, and introduce data entering, transformations, graphing, and regressions. We explain the general concept of linear regression (see screenshot below) and goodness-of-fit via r^2 and residuals.



The use of transformations of data gets the teachers into using formulas in Excel. At this point, we are ready to start constructing Excelets. Here a simple multivariable expression, such as explaining Boyle's Law ($PV = k$) as part of the ideal gas law ($PV = nRT$) allows two new variables (n & T) to be varied in the model by just changing a number in a fixed cell on the spreadsheet. How does varying n or T influence the data and graph? In mathematics, we can explore the influence of the parameters a , b , and c on the quadratic equation, $y = ax^2 + bx + c$. Teachers are now ready to explore and they just created it. Adding the "bells-and-whistles" from the forms toolbar is next in the construction to produce a very dynamic and interactive learning tool. We use the forms toolbar tools since they will function on Mac computers as well as PC's. All the instructions for building Excelets are given at the [Developer's Guide to Excelets](#) website along with over one hundred Excelets in chemistry, mathematics, and other areas. Further resources for mathematical modeling including systems modeling are also provided, as well as links to the Excelets produced by the teachers of the CAST workshops.

Discovery learning is accomplished by the mode of questioning that accompanies the Excelet. Through numerical experimentation using a manipulatable variable, students can predict-test-analyze how this variable influences the data and graph or any calculated parameters. This is the interactive dynamic feature of Excelets.

- Predict: How will increasing (decreasing) the variable influence the data? Make your prediction and sketch a graph of it.
- Test: Increase (decrease) the value of the variable. Remind students to explore the full range of a variable.
- Analyze: What happened? Describe the change, if any, in sound mathematical language. For linear models, we want students to use slope and intercept in their explanations. How did the result compare to your prediction? This is the interpretation and analysis.

Now we can pose some questions for students to ponder. The questions guide the student to explore the model and simulation. We can even get students to discover ideal mathematical relationships using ideal data in an Excelet and then add random and systematic errors to see the real-world data and how it influences the regression results of a model. See the *Investigating the Height of a Stack of Cookies* and *Measuring the Stack Height of Nested Styrofoam Cups* activities and their accompanying Excelets (see table of web-based resources) to explore the scientific and algebraic thinking that students can experience.

A Note to Open Office Calc Users:

Many of the Excelets given in the resources below will function 100% in Open Office Calc, which is open source (free) software available at <http://www.openoffice.org>. Calc functions very much like Excel. You may have to clean up the files for cosmetic reasons, such as the check boxes will become colorless and you will need to hide the words true and false which are under them (turn the font white). If option buttons are on the Excelet, they have a slightly different syntax in Calc and you will have to fix them (amend the formula in Calc) if you want to spreadsheet to function. If you are just getting started with Calc, then see - <http://openofficeschool.org/calc>.

Web-based Resources:

"How to" instructions for Excelets and other modeling stuff	<u>Developer's Guide to Excelets</u>
"Just add data" models to get your students started in modeling	<u>Investigating the Height of a Stack of Cookies</u> (pdf activity) <u>Measuring the Stack Height of Nested Styrofoam Cups</u> (pdf activity) <u>Nested Styrofoam Cups II</u>
Modeling data guide for Excel	<u>Using Excel for Handling, Graphing, and Analyzing Scientific Data: A Resource for Science and Mathematics Students</u>
Downloadable environmental data in Excel format	<u>Quantitative Environmental Learning Project</u>
Get your students graphing data in Excel and performing linear regressions	<u>The Temperature Scales on Thermometers: How are they related?</u> (pdf activity)
Explore graphs and trends in data with no equations!	<u>Patterns in Data: Ideal and Real-world Examples</u>
Learn linear regression	<u>Best-fit Straight Line</u>
The difference between interpolation and extrapolation	<u>Interpolation and Extrapolation</u>
Excelets in chemistry	<u>Chemical Excelets</u>
Excelets in materials science	<u>MatSci Excelets</u>
CAST Resources (other modeling tools as well as Excelets)	<u>Computational Resources</u>
Good mathematics sites using interactive Excel spreadsheets	<u>Flexcel - Flexible Interactive Workbooks in Excel for Maths Teachers</u> <u>Interactive MS Excel Workbooks</u>

For the interested reader:

If you want more on the scatter of data, outliers and how they influence linear models, see -

S.A. Sinex (2005) [Exploring the Goodness of Fit in Linear Models](#), **Journal of Online Mathematics and its Application** 5.

If you want more on random and systematic error in data, see -

S.A. Sinex (2005) [Investigating Types of Errors](#), **Spreadsheets in Education** 2 (1) 115-124.

S.A. Sinex, B.A. Gage, and P.J. Beck (2007) [Exploring Measurement Error with Cookies: A Real and Virtual Approach via Interactive Excel](#), **The AMATYC Review** 29 (1) 46-53. ([Excelet](#))

S.A. Sinex (2008) [Scientific and Algebraic Thinking: Visualizing with Interactive Excel and Nested Styrofoam Cups](#), *On-Line Proceedings of the 34th Annual Conference of the American Mathematical Association of Two-Year Colleges* in Washington, DC.