Using Invention Tasks to Help Students Become Better Scientists

Natasha Holmes, Ido Roll,
Doug Bonn and James Day

Carl Wieman Science Education Initiative
Department of Physics and Astronomy
University of British Columbia

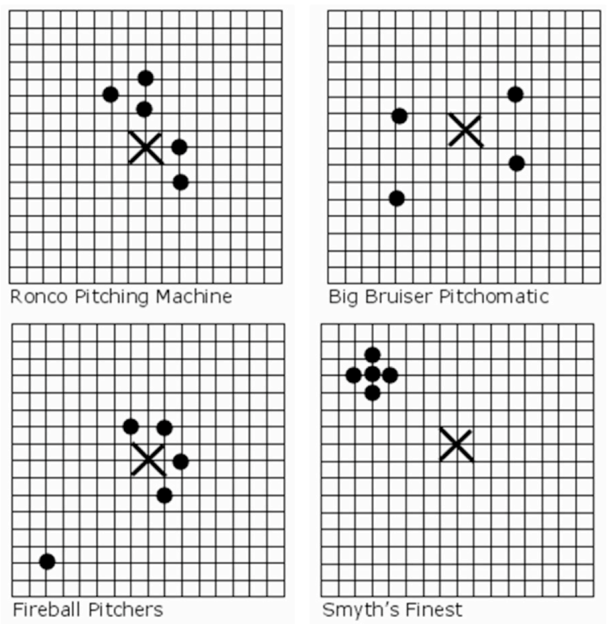
Invention Tasks

- Students invent mathematical methods or solutions to particular tasks, related to their course material, prior and in addition to being taught the canonical solution

- At UBC, activities have been implemented in Phys*107 and Phys*109 labs and various studies have been carried out to date

*Please see the poster by James Day called "Preparing students for learning through invention activities" for a more detailed description of invention activities

Sample Invention:
Pitching Machine/Least Squares Fitting



Here are four grids showing the results from four different pitching machines. The X represents the target and the black dots represent where the different pitches landed. Your task is to invent a procedure for computing a reliability index for each of the pitching machines. There is no single way to do this, but you have to use the same procedure for each machine, in order for the comparison to be fair.

Write your procedure and the index value that you compute for each pitching machine.

Schwartz, D. & Martin, T. (2004)

What this invention taught us:

- Students should be asked to implement their methods
  - If only inventing methods, students do not evaluate their model and often miss features or stop with partial or inconsistent methods
- Instruction prior to invention blocks thinking
  - Students follow instruction rather than reason for themselves
- Context or motivation affects invention
  - Some students did not know what a pitching machine was and thus struggled with relevance or understanding the task

Structured Study

To observe the effects of different levels of support during inventions

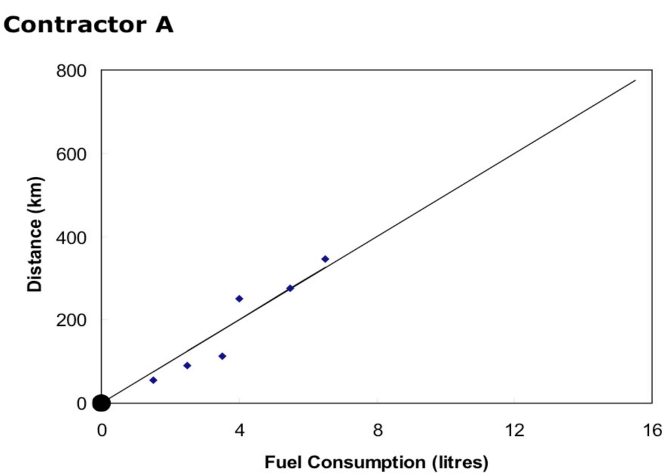
Groups were…	Conventional	Scientific Prompts
Given 4 sets of data all with line of best fit $y=(m+\sigma_m)x$, $m=50$ km/L	X	X
Asked to compare pairs of plots to determine which "does a better job of measuring the slope and why?"		X
Asked to rank all 4 diagrams without calculation and compare with another group		X
Asked to create a method to calculate the uncertainty in the slope, σ_m	X	X
Asked to rank the data sets based on calculations from their formula	X	X

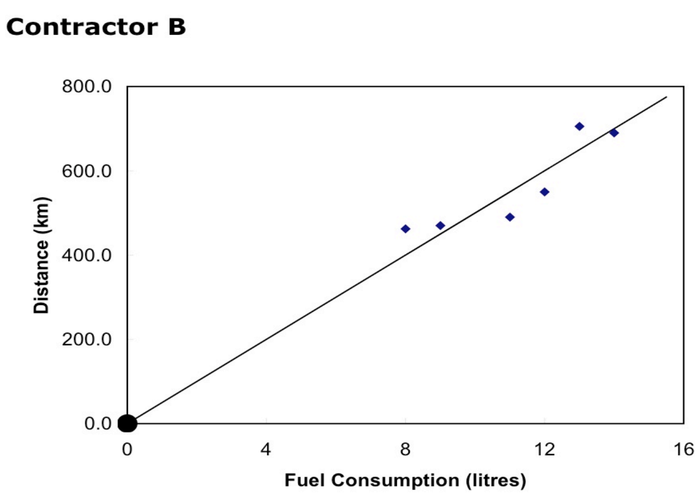
Note: Neither group were given any support at the domain level.

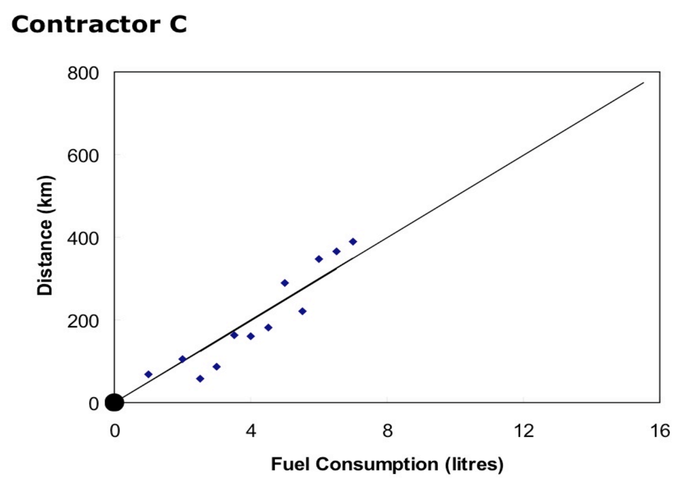
Structured Study:
Finding uncertainty in the slope of a line

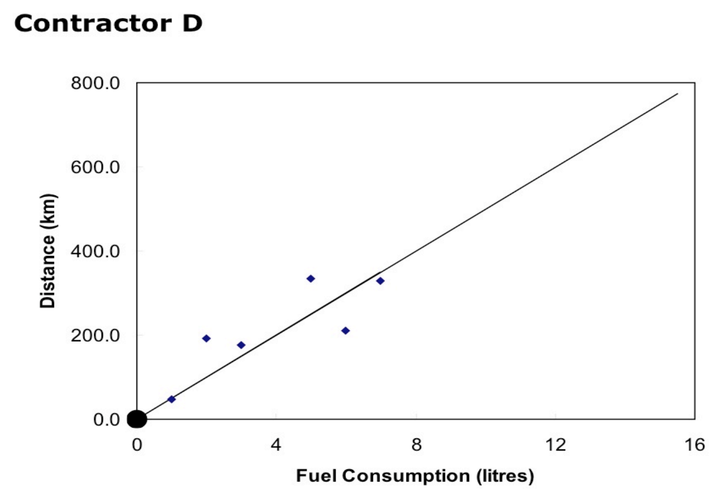
Features

- A vs B: Leverage
- A vs C: Number of data points
- A vs D: Residuals



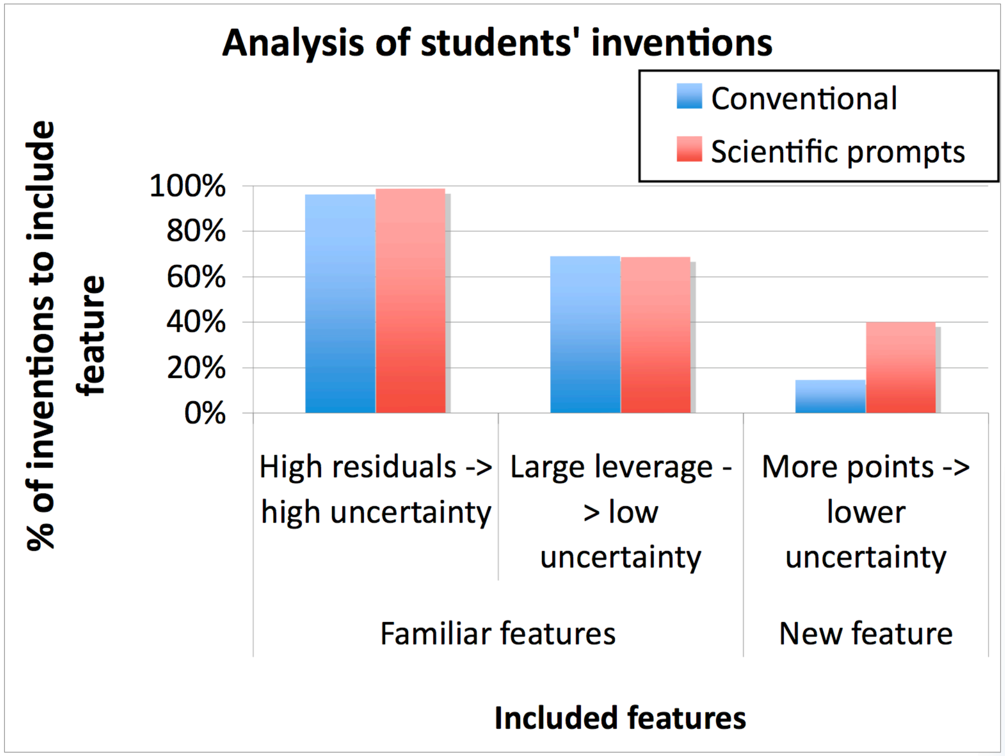






Structured Study Results

- Pair-wise comparisons highlight important features
  - Most students recognized features from other types of uncertainty developed throughout the course and previous invention activities (e.g. χ^2)
  - Groups in the "Scientific Prompts" case were more likely to implement *new* features



Future Work

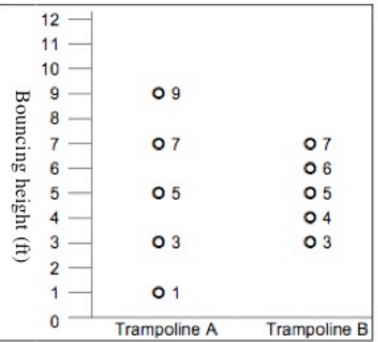
- Intelligent Tutoring Systems (ITS)
  - Implement invention activities on computer interfaces to research:
    - Effectiveness of computer implementation
    - Task delivery and support
  - Advantages:
    - Pedagogical
      - Individual student support
      - Classroom scalability
      - Consistency of optimal delivery/execution
    - Research
      - Log files give detailed analysis of full student inventions
      - Easy to test a variety of cases (e.g. varied structure, support)

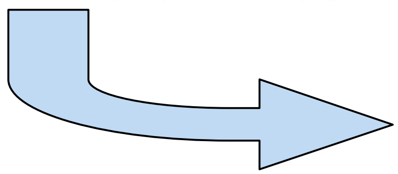
"The Invention Lab"

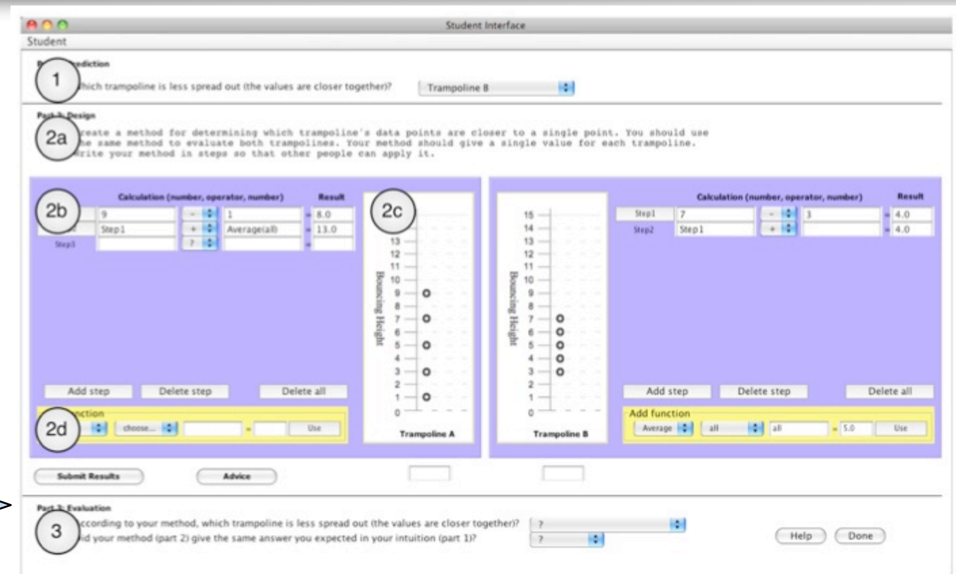
Roll, Aleven & Koedinger (2009; in press)

The Bouncers Trampoline Company tests their trampolines by dropping a 100 lb. weight from 15 feet. They measure how many feet the weight bounces back into the air. They do several trials for each trampoline, and measure only the first bounce in each trial. Here are the results for two of their trampolines:

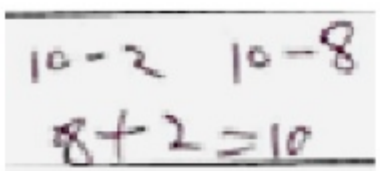
Create a method for determining which trampoline is more consistent. You should use the same method to evaluate both trampolines. Your method should give a single value for each trampoline. Write your method in steps so that other people can apply it.







Roll, Aleven & Koedinger (2009; in press) developed an Intelligent Tutoring System (ITS) for an invention activity to develop the concept of variability at the high-school or middle-school levels



Step1	10	-	2	=	8.0
Step2	10	-	8	=	2.0
Step3	Step1	+	Step2	=	10.0

Example of the same student invention on paper and in the lab

Building from there…

- Highlights of these interfaces:
  - Assign subsequent tasks based on students' progress with previous attempts
  - Enforce development of a single method that is consistent with each case
  - Encourage evaluation of methods
  - Identify errors at the domain level
- Changes or Additions:
  - Input in the form of general equations:
    - At the University level, we wish to encourage scientific reasoning skills and limit undeveloped exploration (trial and error)
  - Vary levels of support:
    - Especially with making pair-wise comparisons or hypotheses, implementing their models or evaluating the solutions they obtain
  - Include support for collaboration
  - Provide multiple tasks

Project Plan

Summer 2010

Design & Build

Using results from current and past studies

↓

Fall 2010

Test with small group of students

Receive feedback from students have completed inventions on paper as well as with ITS

↓

Spring 2011

Implement in Phys*107/109 Labs