

Biot-Savart Discovery Lab and other BS

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Overview

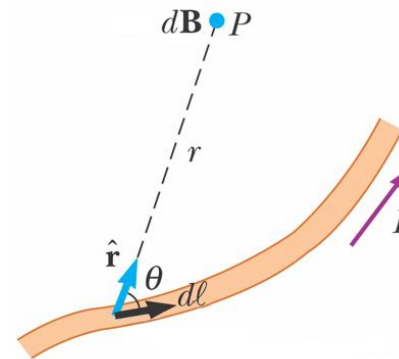
- When students collaboratively collect and analyze data, they can discover relationships that would be difficult to observe independently. An experiment on the Biot-Savart law will be presented as an illustration.
- Students require many skills to succeed in a physics course. Two broad sets, scientific reasoning and problem solving, will be discussed, along with efforts at LMU to help students improve these.

Biot-Savart background

- Much as one can use Coulomb's Law to calculate electric fields due to a collection of point charges, Biot-Savart allows one to calculate magnetic fields due to a collection of infinitesimal currents.

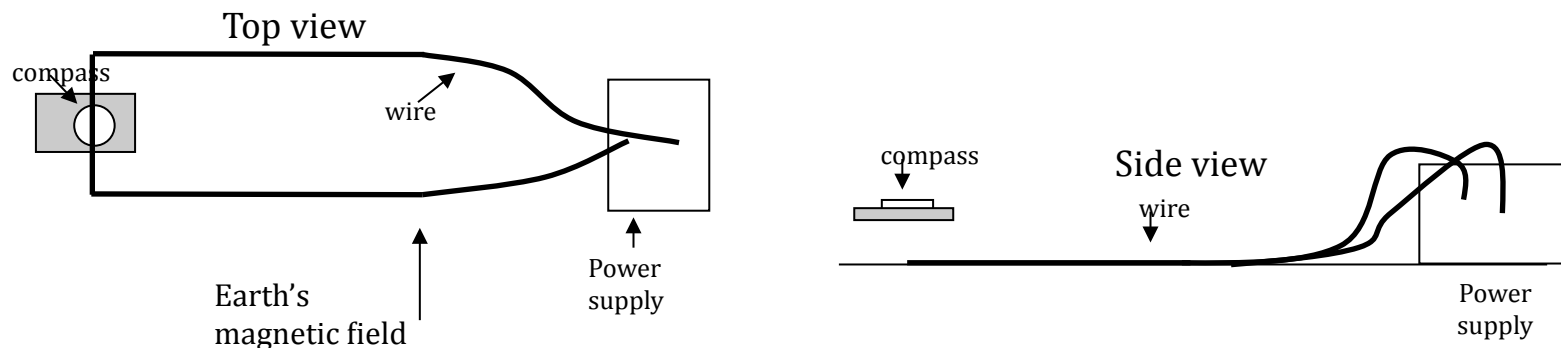
$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{dq \hat{r}}{r^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{\ell} \times \hat{r}}{r^2}$$



Discovery/ observation experiment

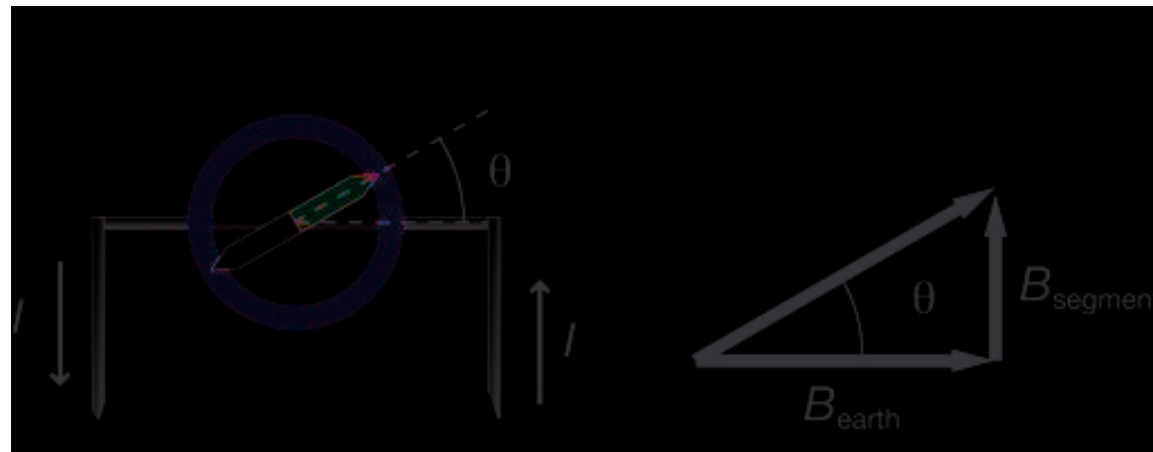
- Each group is given a compass, straight wire segment, connecting wires, ruler and power supply.



- The compass is placed above the middle of the wire segment. The wire segment is aligned with the earth's magnetic field.

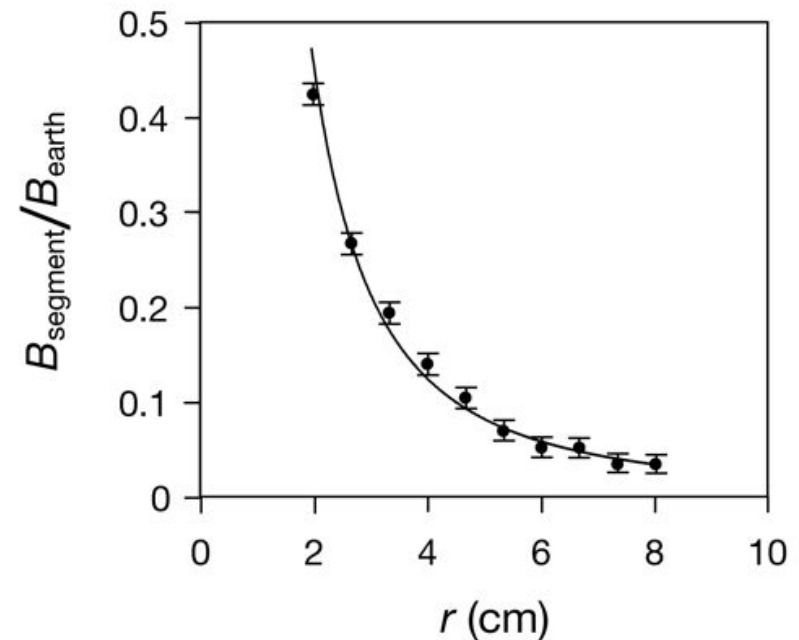
Measuring the magnetic field

- The compass points in the direction of the total magnetic field. This direction can be used to determine the strength of the wire's magnetic field in terms of the earth's.



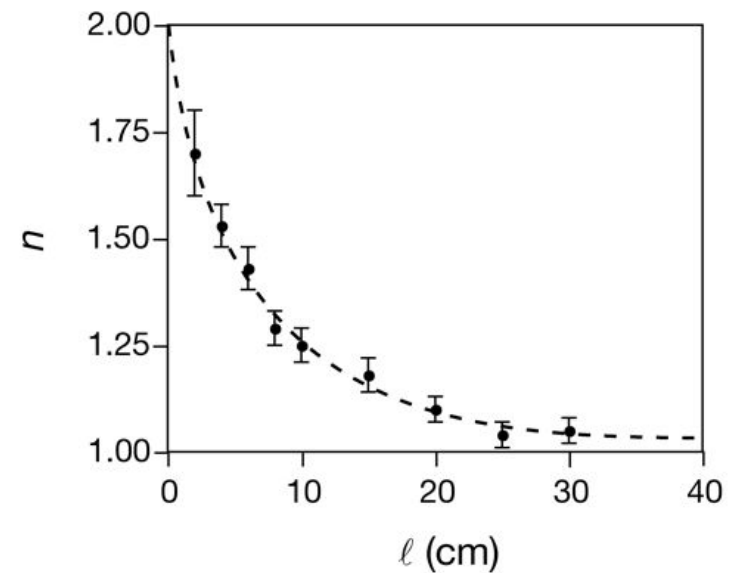
Sample data

- First, students measure the magnetic field as they vary the current with the compass a fixed distance from the wire segment.
- Second, students vary the distance and hold the current constant.
- The data shown to the right was produced with a 4.0 A current. Error bars represent the uncertainty of the compass deflection ($\pm 0.5^\circ$). The fit line is a power law ($1/r^n$) where $n = 1.7 \pm 0.1$.



Where is the infinitesimal part?

- At the end of the lab, each group presents their result. At this time they realize that they all have different results.
- Each group has a different length wire segment.
- By plotting the exponent in their fits as a function of wire length, the class can see the trend as the wire segments become smaller.



Rationale for the design

- Discovery/ observation experiments allow students to conduct authentic scientific investigations. They provide an introduction to the phenomena before the theory, mathematical formulation or other complexities are introduced.
- By varying the setup across student groups, the class can investigate multiple variables at the same time.

However...

- Many students in our classes are not ready to conduct such investigations without significant scaffolding.
- Many students do not have the necessary skills to work with variables.
- Yet even more students lack metacognitive or self-regulating skills which would allow them to conduct independent investigations.
- Prior knowledge also greatly impacts student learning.

Scientific reasoning skills

- Like playing sports, reasoning is a skill that has to be learned and refined over time. The ability to think abstractly is not one that we are born with. Only after many years, do we have the ability to control and isolate variables, search for relationships, such as proportions, understand probability, and lastly, formulate hypotheses and test them with carefully designed experiments.
- One measure of these cognitive skills is the Classroom Test of Scientific Reasoning ("Lawson Test").

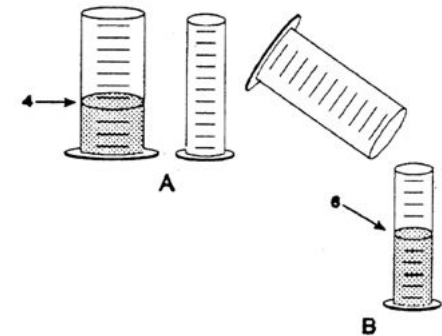
Measuring reasoning skills

- Classroom Test of Scientific Reasoning ("Lawson Test") The 24-question, multiple-choice test probes students' understanding of: conservation of weight & volume, proportional thinking, identification and control of variables, probabilistic thinking and hypothetico-deductive reasoning.

5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).

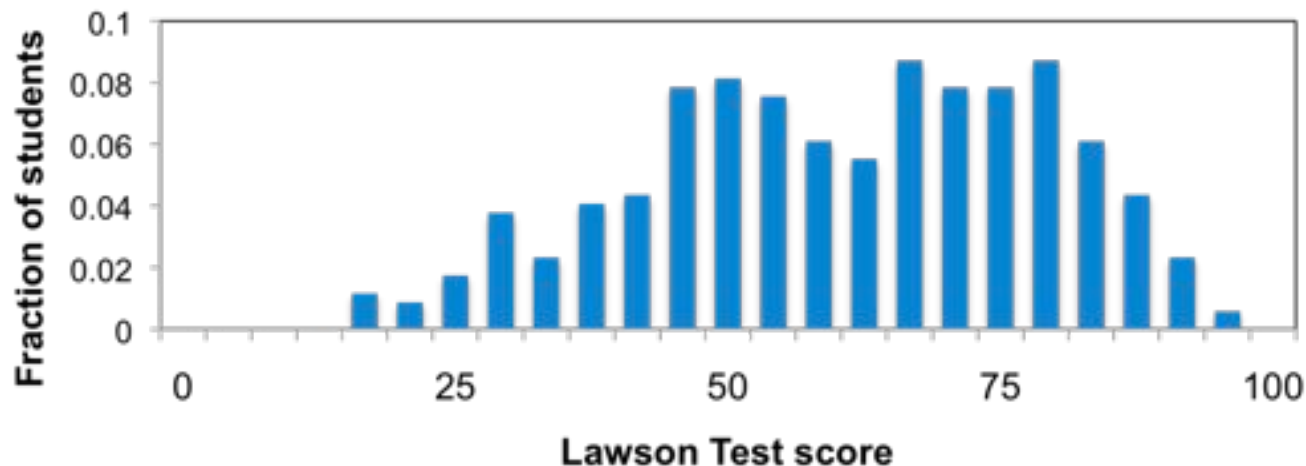
Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. How high would this water rise if it were poured into the empty narrow cylinder?

- to about 8
- to about 9
- to about 10
- to about 12
- none of these answers is correct



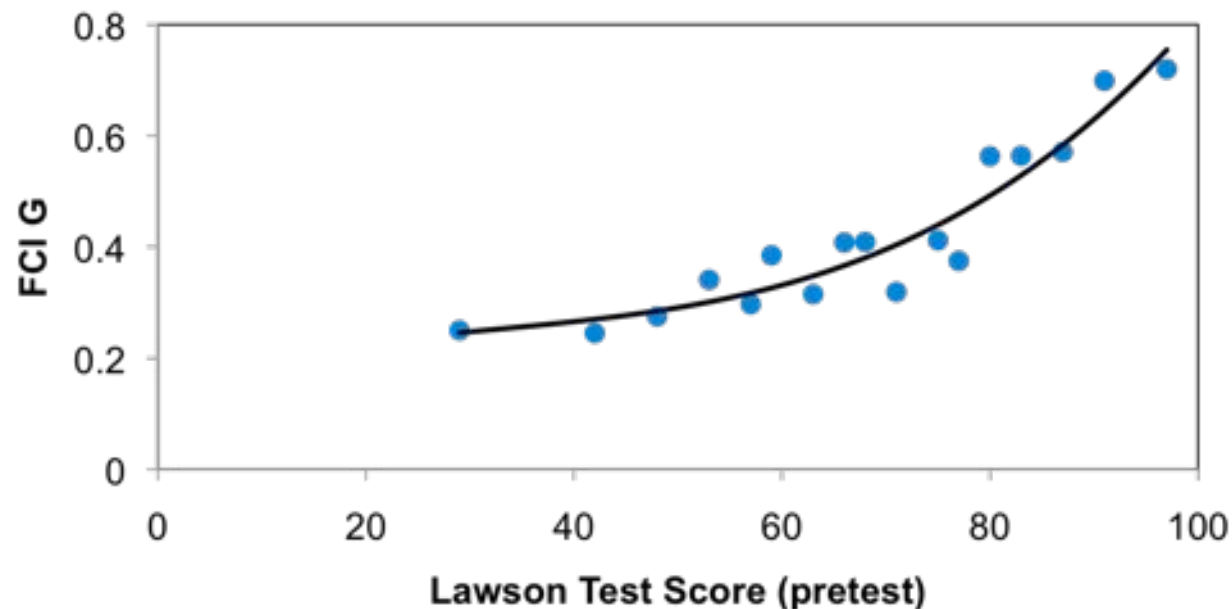
Data on student reasoning

- With the help of the chemistry department we have been able to test freshmen in introductory chemistry. We also have results for sophomore engineering majors in physics 201 and junior biology & natural science majors in physics 253.
- This is a chart below shows the distribution of total Lawson scores among the freshmen.
- Approximately, scores above 75% represent students who have the necessary skills to reason abstractly, and 40- 75% are only possess some of the skills.
- Students who do not have the necessary cognitive skills, will not fully understand abstract concepts such as acceleration and energy.



Impact on conceptual understanding

- The Lawson Test and FCI were administered to 297 high school and university students who were enrolled in interactive courses. (The teaching methods varied across the sections, but all went behind passive lectures.)
- Similar correlations are seen with the SAT.



Thinking in Physics

- A three-year project at LMU, which was funded by NSF.
- Developed curricular materials that targeted students scientific reasoning skills, particularly those related to using variables.
- Different variations were implemented. Some were embedded into existing physics courses and others were separate tutorials or courses.
- Inspired by Cognitive Acceleration through Science Education (CASE).



TIP Activities

- TIP activities often involve student group work, guided by worksheets, including lab experiments.
- Early activities focus on what are variables and the relationships between. Students also develop algebraic and graphic tools to represent the relationships.
- Example activities:
 - One student pulls a cart (sheet of plywood with four low friction, Rollerblade wheels) on which a second student is seated, while maintaining a constant force, which is monitored with a spring scale that is attached to the rope.
 - Groups are given a dozen round, symmetric objects of varying mass, radius, and shape and an inclined plane to investigate what variables affect the time to roll down the plane.

Metacognitive skills

- In addition to the cognitive skills, such as scientific reasoning, problem solving, and mathematical, there are metacognitive skills that are equally important. Thinking about thinking, or metacognition, is important in learning.
- By employing metacognitive skills, one engages in *self-regulated learning*, which can be divided into several sub-skills: planning, monitoring and adjusting.
- These are vital for all activities, but especially problem-solving.

Problem-solving Examples with Narration for Students (PENS)

- Current NSF-funded project, which is developing instructional materials for the classroom.
- The focus is on providing better feedback to the students on their problem-solving process.
- To make what is an internal process “viewable,” students record think-alouds using Livescribe smartpens.
- Collaboration between physics, math, chemistry and education faculty



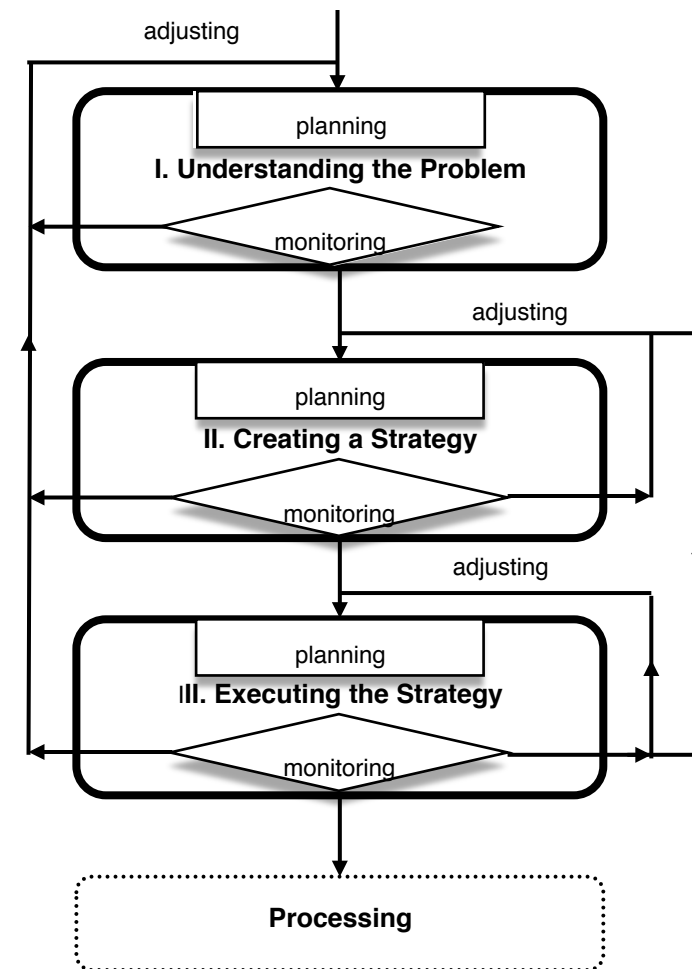
Problems

- By definition what constitutes a problem is dependent on the solver.
- Exercises are questions to which the solver knows the solution immediately.
- General problem solving algorithm (inspired by Polya)
 - Understand the question
 - Create a strategy
 - Execute the strategy



Problems

- Throughout the process the solver must self-regulate- plan, monitor and adjust his/ her thinking.
- Experts solve problems non-linearly, but novices tend to try to solve problems linearly.



Process of problem solving

- Students analyze problem solving process of others and themselves through recorded solutions.
- Sample problem pencasts
 - [kinematics example](#)
 - [freefall example](#)
 - [energy sample](#)
 - [ray optics example \(instructor\)](#)

Observations

- Students can investigate physical phenomena, such as Biot-Savart, before they are discussed mathematically.
- By working with slightly different experimental setups (and sharing data), students can observe variable relationships that aren't seen in a single setup.
- Students often need targeted instruction to sufficiently refine their reasoning and problem solving skills.

Thanks

- If you would like more information about TIP or PENS, please contact Jeff Phillips (jphillips@lmu.edu). You can also visit the LMU PER website
 - <http://myweb.lmu.edu/jphillips/PER>
- For more information on SoCal AAPT section
 - <http://www.scaapt.org>
- Don't forget the upcoming winter AAPT meeting, which will be in Ontario, CA February 4-8
 - <http://www.aapt.org>