Investigating student understanding of observational astronomy: the Sun

Amy Webber
Physics Education Group
University of Washington

Physics Education Group

Faculty

Lillian C. McDermott
Paula Heron
Peter Shaffer

Visiting Faculty

Paul van Kampen (Dublin City Univ.)

Research Coordinator

Karen Wosilait

Support Staff

Nina Tosti

Post-docs & Lecturers

Lezlie S. DeWater
Donna Messina
MacKenzie Stetzer

Physics Ph.D. Students

Hunter Close
Matt Cochran
Sean Courtney
Andrew Crouse
Mila Kryjevskaia
Beth Lindsey

Physics Masters Students

Julie Crockett
Matt Hahn

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Why is Physics Education Research important and in what ways is it helpful?

- Certain conceptual difficulties persist, even after traditional, lecture-based instruction
- Often neither a deep conceptual understanding nor a strong foundation for reasoning ability follow from this type of instruction.

  "Teaching by telling" is not the most effective instructional strategy for the majority of student learners.

Data from *Am. J. Physics 69 (11)* "Oersted Medal Lecture 2001", Lillian McDermott.

What is Physics Education Research?

- Iterative process of research, curriculum development, and instruction
- As implemented at UW:
  - Research: exploratory interviews, pretest and post-test analysis, observations in classroom
  - Curriculum development: *Physics by Inquiry* and *Tutorials in Introductory Physics*
  - Instruction: introductory and advanced physics courses, inservice and preservice teacher courses

Curriculum Development: What strategies are used?

An example: e*licit, confront, and resolve*

- Pretests: students commit to answers regarding a topic about which data suggests common errors are made
- Curriculum: students led to recognize any inconsistencies or gaps in reasoning and how to resolve; exercises and experiments deepen conceptual understanding and address any remaining difficulties.

Curriculum Development: What strategies are used? (*cont'd*)

Single instructional experience not sufficient to resolve all difficulties

- Students often fail to generalize subject matter for use in physical situations not specifically taught
  - Opportunity to *apply, reflect,* and *generalize* in homework assignments and additional worksheets

Instruction: How do we avoid "teaching by telling"?

- "Guided inquiry"
  - Instructors do not give answers but rather ask questions.
- No lecture-based curricula
  - Lab-based: students perform experiments that provide basis for development of scientific concepts
  - Students work in small groups on exercises with specially designed sequencing of questions
  - "Check-outs" at the end of specified sections
    - Instructors ask questions and guide students through difficult areas.
- Instructional approach especially important for teachers
  - Opportunity to study material in depth
  - Learning style consistent with how they are expected to teach

Research: A specific case

- NSF Summer Institute 2005: Astronomy by Sight Sun afternoon curriculum (30 hours total) - 2 sessions
- First session (high school): 20 participants
  - 50% had taught astronomy before
  - Of those, 20% had specifically taught sun-related topics

Overview of Astronomy by Sight Curriculum

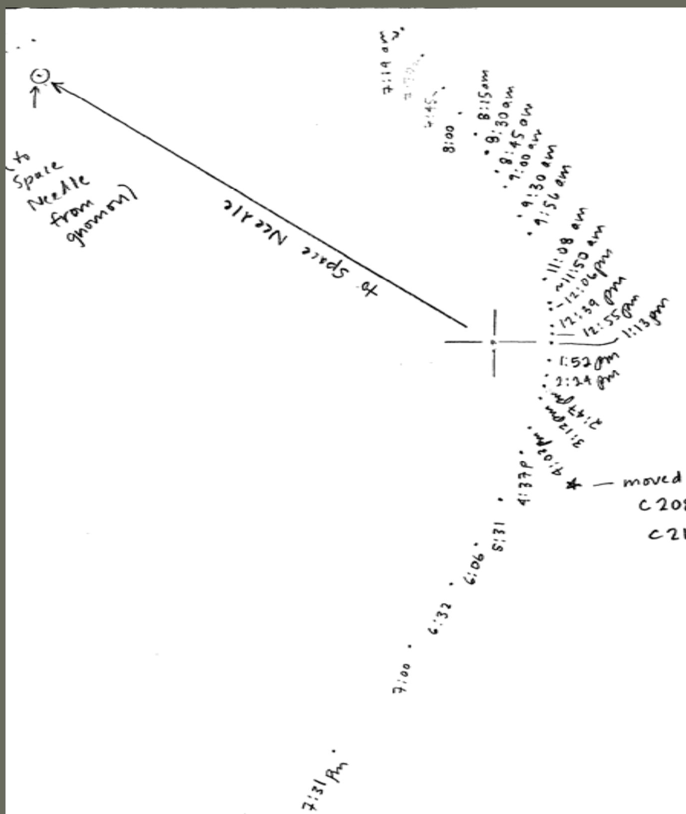
- Emphasis on scientific process
- Importance of making predictions and following those predictions with observations that either affirm or disagree with predictions
- Stress operational definitions
  - Example: local noon, cardinal directions (N, S, E, W)
- Based on the observations actually made, a physical model is developed
  - Round earth, far sun
  - Geocentric and heliocentric

Original predictions: Pretest 1 (2005)

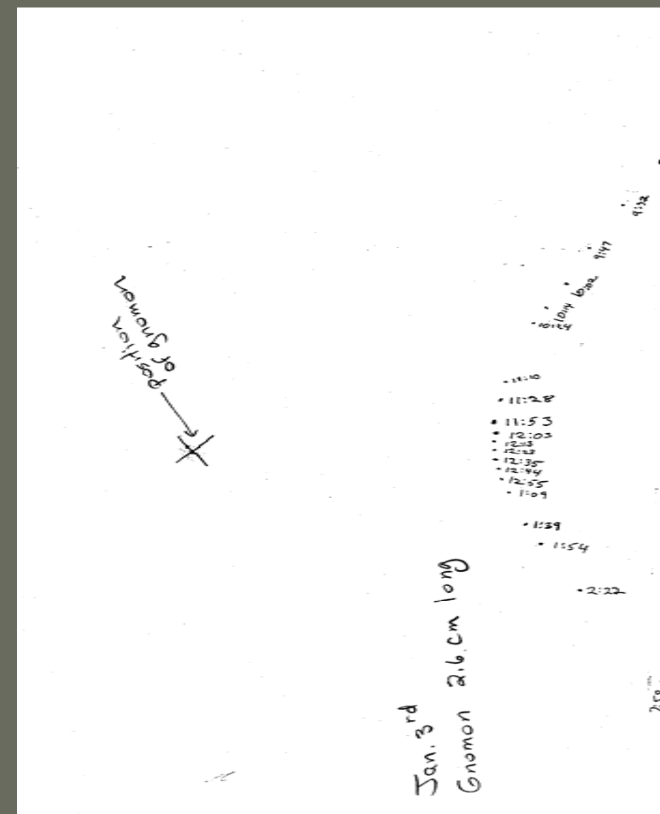
Predict shape traced out by tip of shadow of vertical object (gnomon) throughout the course of a day in both January and in June

- Only 10% correct
- Nobody who had previously taught sun-related topics made correct predictions

Shadow plot: primary means of observation

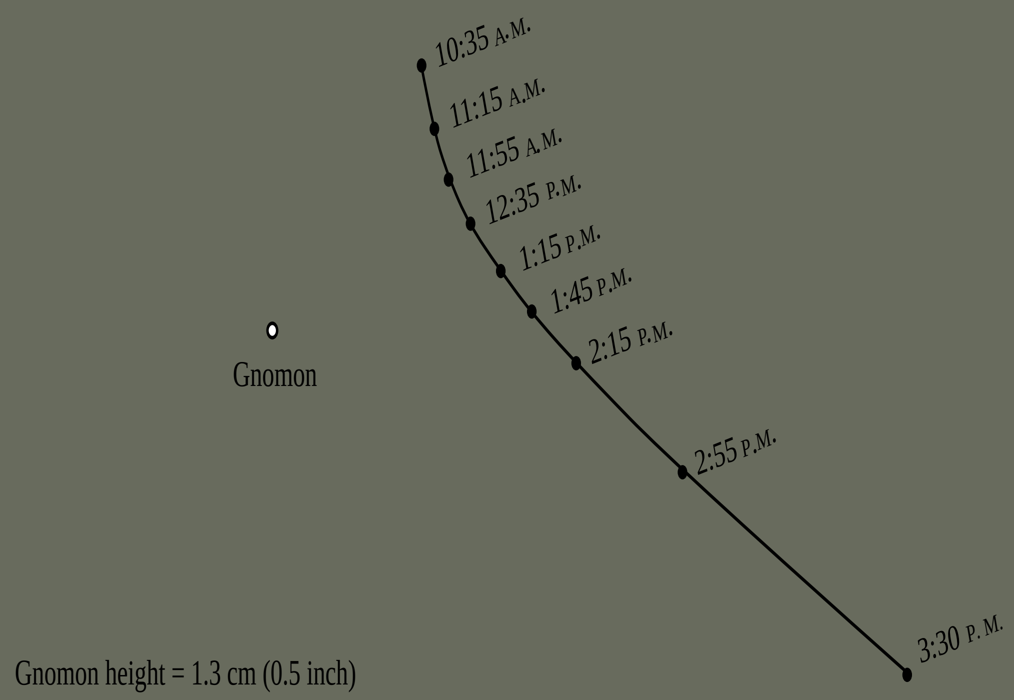


Shadow plot made June 24th; gnomon height = 2.9 cm



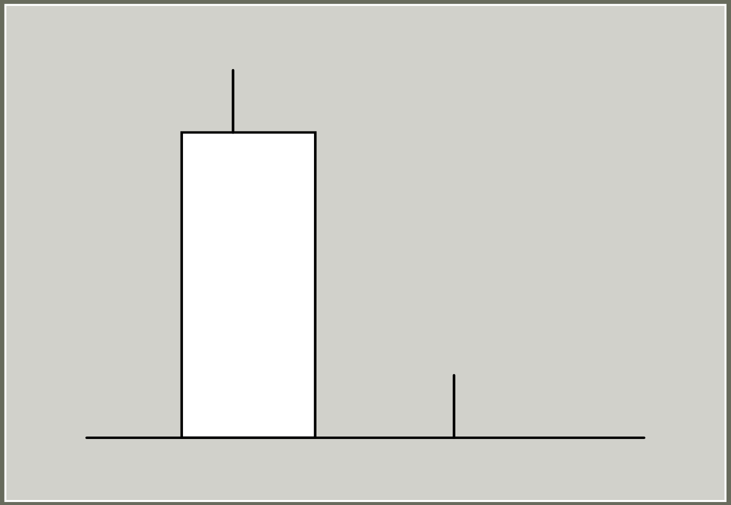
Shadow plot made January 3rd; gnomon height = 2.6 cm

Curriculum assessment: a post-test



- Teachers generally perform well

Analysis of previous pretest data

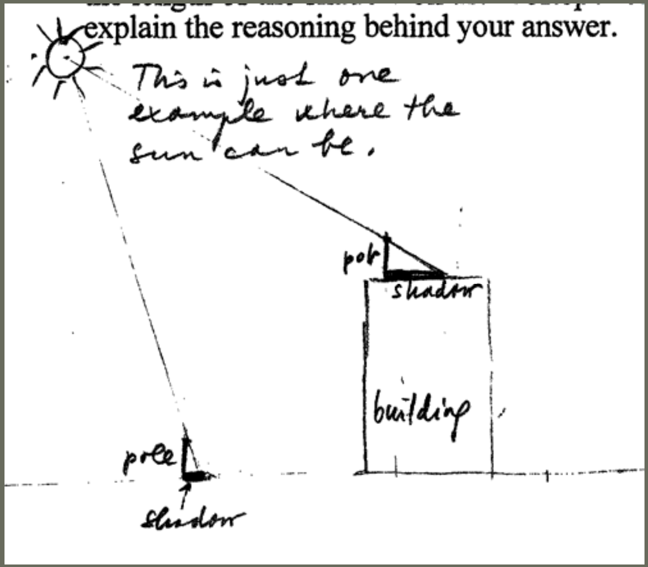


- Compare shadows cast by two poles
  - Top of building
  - Ground-level

- Completely correct response
  - Sun is very far away
  - Incoming rays from a point on the sun parallel
    - Altitude of sun is identical for both poles
    - Shadow lengths are same

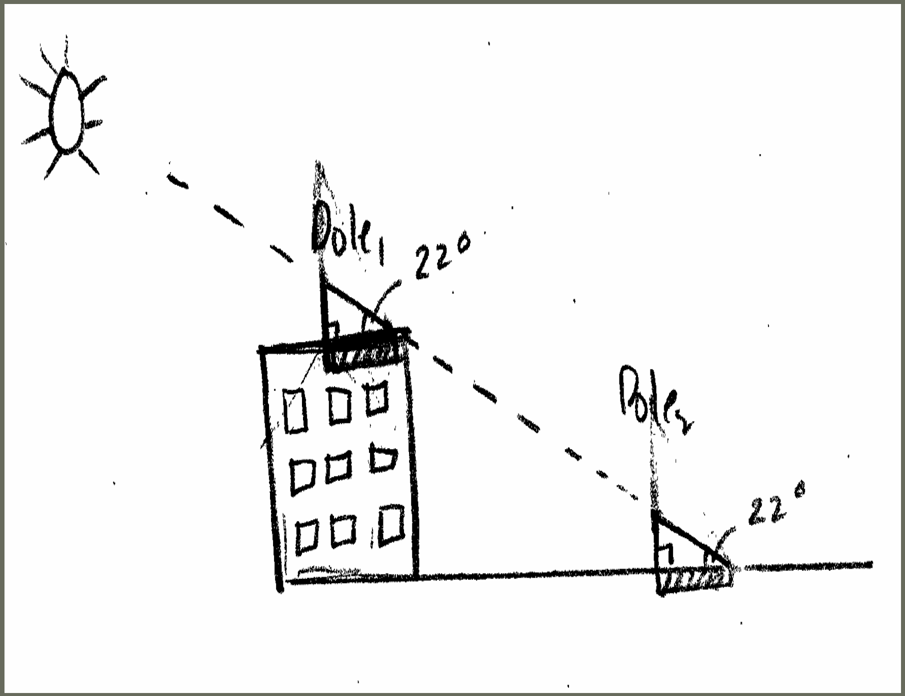
Analysis of previous pretest data *(cont'd)*

correct	60%
completely correct	10%
'limiting argument'	10%
close sun	20%
misunderstood question	10%



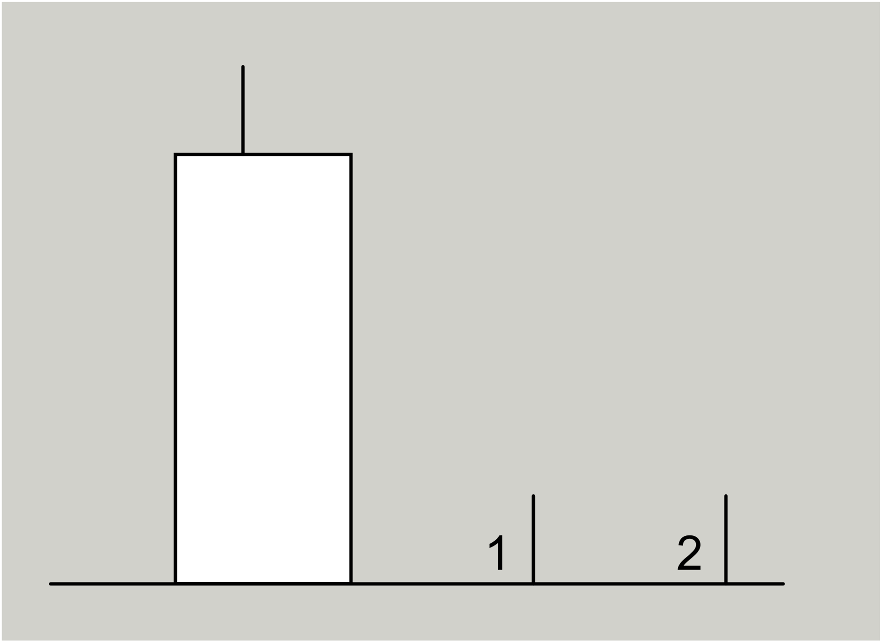
close sun diagram

Analysis of previous pretest data *(cont'd)*



- Difficulty interpreting responses: diagrams accompanying answers (17%)
  - Single ray emanating from a sun (sometimes close) through both poles
    - *Why was this difficult?*
  - Suggested revision*:* Add an additional pole on ground
    - *How this helps:* Forces students to draw additional ray; allows us to see whether this ray is parallel to others

2005 Revised pretest



- Compare shadows:
  - Roof and ground pole #1
  - Ground poles #1 and #2

- Completely correct response
  - Sun is very far away so incoming light from sun is parallel
    - Altitude of the sun is the same for both poles
      - Shadow lengths are same

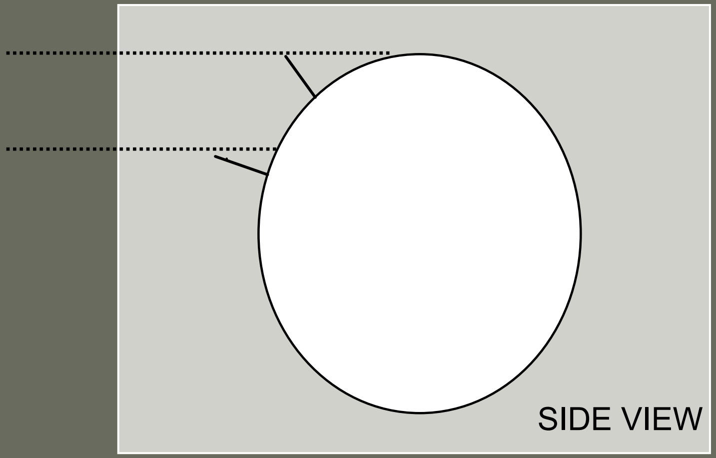
How our revision changed question interpretation and data analysis

- Diagrams much clearer - able to tell what students were thinking (none drew single ray through both gnomon)

	Pre-modification	Post-modification (2005)
correct	60%	45%
completely correct	10%	15%
‘limiting argument’	10%	10-35%
close sun	20%	25-50%
misunderstood question	10%	none

Parallel-ray/close sun problem - another look: Pretest 5 (2005)

- Pretest Question (part B) - given after some instruction regarding distance to sun in Section 3
  - analyzed a close sun diagram and pointing out what is wrong
  - thought about how distance to sun predicts parallel sun rays
- Compare length and direction of shadow at same time for two observers oriented 500 miles apart along a north-south line



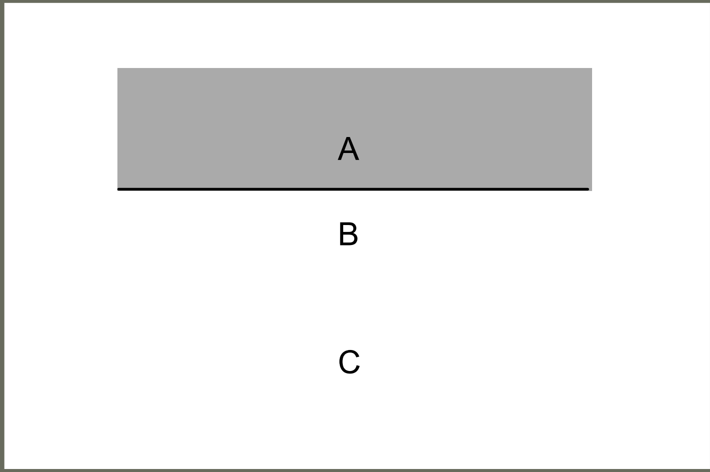
- Completely correct response (include diagram)
  - Shadow of southernmost student is shorter
    - Sun is very far away and so light from sun is parallel
    - Curvature of earth is such that altitude of sun greater for southern student

Parallel-ray/close sun problem: another look: Pretest 5 (2005) *(cont'd)*

correct	70%
completely correct	20%
'limiting argument'	15%
close sun	25%

- 65% drew diagram to accompany response
  - Of those, 35% drew close sun with rays emanating from a point on the sun not parallel

Cliff post-test question: a final check

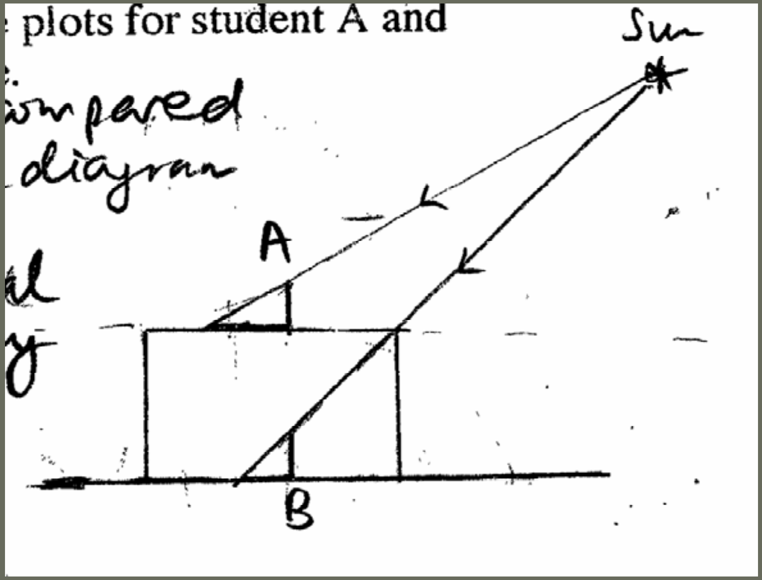


- Three students along a north-south line make shadow plots on the same day. Compare shadow plots of:
  - Students A and B
  - Students B and C
- Completely correct response

	Pretest	Post-test
correct	45%	95%
completely correct	10%	20-40%
‘limiting argument’	10-35%	45%
close sun	25-50%	5%

Post-test diagrams: insight

- 30% drew diagrams with sun close to earth
  - For 20%, diagram affects perception of subject matter



Modification of module to address common misconception of a close sun

- Students asked to think about physical model (which has close lightbulb sun) developed in section six in terms of a small observer on a large, round earth
  - Consistency between sections six and seven requires further consideration of far sun/parallel ray idea

Summary and Conclusions

- Even after instruction, teachers have difficulty:
  - Generalizing observations to accurate physical model
  - Consistently describing physical model developed, both in words and with diagrams
- Second session: implemented revised sections six and seven