Putting Principles of Science Education into Practice:

Transiting Planets Lab at Hartnell Community College

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Context for Discussing Science Teaching

Professional Development Program through UC Santa Cruz:
Center for Adaptive Optics (CfAO) / Institute for Science and Engineer Educators (ISEE)

- series of intensive workshops on teaching science
- ~6 months designing and then teaching a hands-on science activity for affiliated program

We’d like to share what we’ve learned and our teaching experiences, and stimulate discussion about teaching in the Berkeley Astronomy community.

Talk Outline:
- Some principles of science education
- Our teaching activity
- Discussion in context of Berkeley Astronomy community
Goals for Science Education

Students . . .

• learn about the natural world

• learn reasoning skills to address diverse problems

• appreciate how science is valuable to human knowledge and culture

• understand the characteristics and limitations of scientific knowledge

• learn and practice quantitative analysis

• learn how science and technology are relevant to present-day geopolitical and social issues

• see potential doorways to future careers in science

• develop skills and knowledge they can apply directly to scientific research
Teaching Science: Supporting Documents

How People Learn (1999)
Committee on Learning Research and Educational Practice

National Research Council

"[Authentic Inquiry in Schools]" (2002)
Chinn, C. & Malhotra, B., Science Education

Understanding by Design (1998)
Wiggins, G. & McTighe, J.
Science Process Skills:
What does a scientist do?
What does a scientist do?
(entry-level undergrad’s list)

• Hold a knowledge base about natural phenomena, and apply prior knowledge to new observations
• Use math
• Perform measurements and interpret patterns in data
What does a scientist do?
(graduate student’s list)

• Hold a knowledge base about natural phenomena and apply prior knowledge to new observations
• Use math
• Perform measurements and interpret patterns in data
• Ask original questions
• Assess uncertainties and shortcomings in data
• Consider competing explanations
• Synthesize other researchers’ results
• Explain results and discuss new research directions, both formally and informally
• Distill technical knowledge for public consumption; convey the broader significance of specific findings
What does a scientist do?
Examples from Taking Science to School (2007) and Chinn & Malhotra (2002)

• “invent or construct variables that are conceptually embedded in the theories being tested”

• “[connect] the manipulated and measured variables […] to the theoretical variables of interest through […] indirect chains of inference”

• “[make] difficult decisions about whether the processes in the experiment overlap sufficiently with the assumed processes in the real world to make the experiment meaningful”

• “adopt[ ] a critical stance, a willingness to ask questions and seek help, and […] a sense of appropriate trust and skepticism”
“In science, content and process are inextricably linked.”

Ready, Set, Science!

“Current research indicates that proficiency in one aspect of science is closely related to proficiency in others (e.g. analytic reasoning skills are greater when one is reasoning about familiar domains).”

Taking Science to School
“Viewing the science classroom as a scientific community akin to communities in professional science is advantageous.”

Taking Science to School
How People Learn (1999)

Key Findings / Principles:

1.) Learners’ preconceptions strongly influence their interpretation of new concepts. For new lessons to endure, teachers must solicit and directly engage students’ initial understanding.
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- Learners’ preconceptions strongly influence their interpretation of new concepts. For new lessons to endure, teachers must solicit and directly engage students’ initial understanding.

“‘Students’ initial ideas about mechanics are like strands of yarn, some unconnected, some loosely interwoven. The act of instruction can be viewed as helping the students unravel individual strands of belief, label them, and then weave them into a fabric of more complete understanding.’”

James Minstrel, high school physics teacher
How People Learn (1999)

Key Findings / Principles:

2.) Factual information can be most easily recalled and most broadly applied when it is learned within the context of a conceptual framework. Curricula must address topics in sufficient depth for students to learn the underlying framework.
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- Factual information can be most easily recalled and most broadly applied when it is learned within the context of a conceptual framework. Curricula must address topics in sufficient depth for students to learn the underlying framework.

“Experts, regardless of the field, always draw on a richly structured information base; they are not just ‘good thinkers’ or ‘smart people.’”
How People Learn (1999)

Key Findings / Principles:

3.) Teaching metacognitive strategies helps students become independent learners. Applying metacognitive activities to specific content helps students build the mental processes used by experts.
Teaching metacognitive strategies helps students become independent learners. Applying metacognitive activities to specific content helps students build the mental processes used by experts.

“Research has demonstrated that children can be taught these strategies, including the ability to predict outcomes, explain to oneself in order to improve understanding, note failures to comprehend, activate background knowledge, plan ahead, and apportion time and memory. [...] Ultimately, students are able to prompt themselves and monitor their own comprehension without teacher support.”
How People Learn (1999)

Key Findings / Principles:

• Learners’ preconceptions strongly influence their interpretation of new concepts. For new lessons to endure, teachers must solicit and directly engage students’ initial understanding.

• Factual information can be most easily recalled and most broadly applied when it is learned within the context of a conceptual framework. Curricula must address topics in sufficient depth for students to learn the underlying framework.

• Teaching metacognitive strategies helps students become independent learners. Applying metacognitive activities to specific content helps students build the mental processes used by experts.
Backward Design
(Principles for Planning Effective Learning Activities)
based on Wiggins & McTighe (1998)

- Effective activity (or curriculum) planning begins with determining learning goals for students. The structure and details of the activity are then developed to support these goals.

- Assessment of students’ progress is crucial. Assessment informs both the goals (which much be defined such that assessment is possible) and the activity (which should contain elements for formative assessment as students progress).
Putting Principles of Science Education into Practice:

Transiting Planets Lab at Hartnell Community College
Activity Overview
Design and teach a 3-hour activity in intro astronomy (non-major) lab course at Hartnell Community College (Salinas)

Topic: Transiting Planets

Anne Medling
(UCSC astronomy grad student)

Prof. Pimol Moth
(former UC Berkeley undergrad!)

also with: Lisa Hunter, Ryan Montgomery, Lynne Raschke
Our Activity Goals

Students should ...

1. Devise their own questions about planetary systems.

2. Construct a light curve from their own measurements.

3. Deduce relative properties of planetary systems from transit light curves (e.g., planet’s radius, orbital inclination).

4. Present their work clearly and coherently.

5. Connect the activity content to current transit searches (e.g. Kepler mission) and see that scientific discoveries are ongoing.
Model Planetary System:

- light bulb ("star")
- foam ball ("planet") mounted with arm on lazy susan bearing
- light meter with cardboard "telescope"

many available materials, including:
- various sizes of light bulbs, foam balls
- clay (for inclining the system)
- wire, felt, rulers, construction & wax paper, etc.

Transit!
Activity Timeline (3 hours):

1. Introduce activity
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1. Introduce activity

2. Review idea of transiting planets (slideshow)

Light curve for the star OGLE-TR-56:
host of the first planet detected via transit method

from F. Pont et al. 2006, Astronomy & Astrophysics, 465, 1069
[edited by L. Strubbe]
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
4. Investigate questions with model planetary system
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
4. Investigate questions with model planetary system
5. Present findings to classmates
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
4. Investigate questions with model planetary system
5. Present findings to classmates
6. Recap what we learned (slideshow)
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
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4. Investigate questions with model planetary system
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6. Recap what we learned (slideshow)
Focus on Backward Design for Activity Goal #1: Asking Questions

Students should ...

1. Devise their own questions about planetary systems.

Rationale

Asking questions helps students...

- follow up their curiosity, deepen their understanding
- learn in future classes and continue learning in everyday life
- more effectively communicate and learn from other people
- take charge of their own learning
Focus on Backward Design for Activity Goal #1: Asking Questions

2 activity components to support this goal:

- Developing their own questions to investigate
- Asking questions during presentations
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
4. Investigate questions with model planetary system
5. Present findings to classmates
6. Recap what we learned (slideshow)
Developing Their Own Questions to Investigate

1. students play with model planetary systems

2. students brainstorm first impressions individually
Focus on Backward Design for Activity Goal #1: Asking Questions

Word Box

This is a list of words that might inspire questions or observations during today’s activity. You can look at this page any time during the activity. It might be especially helpful when you are first using the lab equipment, and when you are working on the Question Recording section that follows.

light curve
twice as long
planet
planet’s size
brightness
bigger
longer
half as deep
shorter
twice as bright
star’s size
transit
fainter
dip
smaller
edge-on
face-on
twice as big
radius
orbital period
star
brighter
inclination
time
Developing Their Own Questions to Investigate

1. students play with model planetary systems
2. students brainstorm first impressions individually
3. instructors introduce refining impressions into investigable questions
4. students individually refine first impressions into questions
5. small groups refine and select favorite questions
6. groups share favorite questions with the class; instructors classify as “Investigable Today” and “Not Equipped”
Focus on Backward Design for Activity Goal #1: Asking Questions
developing their own questions to investigate

Examples of Students’ Questions:

- How can the size of the planet be determined?
- Can you learn about the size of the planet by looking at its transit?
- How does the ratio of sizes of star and planet affect the transit?
- How does the brightness of the star affect how well we can detect the planet?
- In what ways does the inclination of a planet affect the transit?
- Is it possible for a planet to be present but undetectable due to the system being tilted?
- Would a planet with a tilted orbit be harder to find?
- Can you tell if a planet has a ring?
- Can you tell if a planet has an atmosphere when it is transiting?
- Can we detect what a planet is made of by looking at its reflected light?
Activity Timeline (3 hours):

1. Introduce activity
2. Review idea of transiting planets (slideshow)
3. Develop their own questions to investigate
4. Investigate questions with model planetary system
5. Present findings to classmates
6. Recap what we learned (slideshow)
Focus on Backward Design for Activity Goal #1: Asking Questions

Asking Questions During Presentations

- Each group gave poster presentation with long time allotted: (3 min speaking + 3 min questions)
- included suggested Audience Question Prompts, e.g.:

- Can you explain why your result is true?
- How did you come up with the plan for your investigation?
- If you had another hour to continue your investigation, what might you do?
- Did you learn anything that surprised you?
Qualitative Results:
Written Student Feedback

“I really liked that we had to think about how we were going to answer
the question that we chose; even though it is frustrating, it feels good to
think like that.”

“It was good; rather than listening to what they say, we physically did it.”

“It made us think like real astronomers, build our own question,
hypothesis and make our own data. It’s always nice to be able to do this.”

“Interesting, made me think which hurted the head. Coming up with our
own questions and steps to prove whether the question was right involved
much thought.”

“Because it was our own experiment, I felt like I was a scientist.”

(anonymous post-activity surveys)
Quantitative Results in Progress: Pre- and Post-course Surveys on Attitudes about Science

Students rate their level of agreement (from 1-5):

Confidence as a Scientist
e.g., “I am confident that I can ...
... generate questions from the data that I can use to further investigate.
... think independently and develop my own procedure to find results.”

Identity as a Scientist
e.g., “I have a strong sense of belonging to the community of scientists.”
“I have the skills to be a scientist.”

Commitment to a Science Career
e.g., “I intend to work in a job related to science.”
“I am open to the idea of a career in science in the future.”

compare survey results from Spring 2009 (no inquiry activities) and Fall 2009 (2 inquiry activities)
Teaching in the Berkeley Astronomy Community
Positive Examples and Potential Improvements

Some ideas:

- Set aside several consecutive lectures and/or discussion sections to address one topic in depth
- Use exploratory activities that allow students to guide their own learning
- Foster a positive environment for students to take risks
- Lab courses plus AY199 (Research Presentation) cover an extensive range of research process skills and discourse.
- Spend time to explicitly teach and model metacognitive strategies
  - For example:
    - Instructors can present their inner monologue out loud when addressing a student’s question in class
    - Order of magnitude arguments, with explicit description of their role in problem-solving
    - Astro-ph coffee is a good setting for graduate students to see other researchers model metacognitive processes
- In addition to addressing common misconceptions, actively encourage students to share their individual prior understanding
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(specifically cited by How People Learn)

www.reducingstereotypethreat.org

Steven Stroessner, Catherine Good & Lauren Webster

website includes a bibliography of research articles on stereotype threat

Copy of bibliography: astro.berkeley.edu/~nmcc/teaching