Incorporating inquiry into education programs at the Center for Adaptive Optics

A panel presentation by:

Lisa Hunter
Barry Kluger-Bell
Lynne Raschke

Seth Hornstein
Anne Metevier
Jason Porter
Outline

• Overview and context (Lisa Hunter)

• Training CfAO graduate students and postdocs to teach with inquiry (Barry Kluger-Bell)

• Teaching with inquiry: CfAO graduate students put into practice what they learned
  – Lynne Raschke: Setting goals
  – Seth Hornstein: Design and preparation
  – Anne Metevier: Facilitation
  – Jason Porter: Incorporating elements of inquiry

• “Science Community Posters” displayed from 5-6 at reception
Center for Adaptive Optics

- Science and Technology Center, funded in 1999
- Headquarters at UC Santa Cruz
  - Director: Jerry Nelson
- 11 university nodes
  - Over 40 partner institutions (research, education, gov., industry)
- Combines education with research and development in three science and technology areas.
- Education and Human Resources budget is ~15% of budget (~$500K)
## Overview of CfAO EHR goals

**Goal #1:** Versatility for broad career paths

**Goal #2:** Motivation, Preparation, Retention in STEM

**Goal #3:** Knowledge & interest in CfAO related science and technology

**Goal #4:** Recruitment and retention of underrepresented groups

### Core Programs

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<tr>
<th>Elementary</th>
<th>Middle school</th>
<th>High school</th>
<th>Undergraduate</th>
<th>Grad school</th>
<th>Postdoc</th>
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<tr>
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### In-Formal & Supplemental Education

- Knowledge & interest in CfAO related science and technology (Goal #3)

### Major Strategies in Y1-5:
- Inquiry
- Mentoring
National recommendations for improving graduate education

- Adequate mentoring (broad careers, multiple mentors, mentor training, community, etc.)
- Exposure to wide variety of career options
- Better teaching preparation for variety of settings, and using research-based pedagogical tools
- More connected to needs of society and global economy
- Balance between disciplinary depth and interdisciplinary challenges

Great resource: “Re-envisioning the Ph.D.”
http://www.grad.washington.edu/envision/index.html
Research on how people learn science tells us a lot – how do we get the next generation to put it into practice?

Decided on a workshop focusing in inquiry. Experimental!
  - How much educational research?
  - What is the right length of time for the workshop?
  - Lots of raised eyebrows: “graduate students want to do research, they won’t be interested”...
  - Will participants really be able to put it into practice?
CfAO EHR Core Programs: A place to teach using inquiry

Core CfAO Programs:

Stars, Sight and Science
- High school level
- 4 week summer science program

College Internship (REU)
- Includes 4-day orientation for preparation and community building

Need:
Develop and teach new instructional components for two programs.

Focus:
Inquiry
“Integrating Research and Education”
a professional development workshop

4-day workshop for ~30 CfAO graduate students and postdocs.

Components:

- Using inquiry to teach science (75% of workshop)
- CfAO community & collaborations
- Technical facilities tour
- Community Partnerships
- Science Community Posters
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Exploratorium

Center for Informal Learning and Schools

Institute for Inquiry
Dr. Barry Kluger-Bell
Assistant Director for Science

October 26, 2002
Why we work with CfAO

Traditional forms of science instruction are failing many of our students, particularly those who will become teachers.

The CfAO graduate and post-doctoral students represent the next generation of college teaching. It is imperative that they experience alternate forms of education so they have the tools to reverse this failure.
Integrating Research and Education

GOALS

1/ CfAO students become reflective about teaching and learning

2/ CfAO students experience efficacy of inquiry teaching and learning

3/ CfAO students consider moving their teaching toward an inquiry approach

4/ CfAO students become part of the education as well as the research community
Integrating Research and Education

ACTIVITIES

• Two Kinds of Hands-on Learning – Shifting Activities
• Student Panel – “What we did to get inquiry in our teaching.”
• Reading and Discussion About Learning and Teaching
• Inquiry Experience
• Design of Inquiry Activity
The Gray Step Illusion Inquiry

Map of Inquiry Structure

Inquiry Starter

Focused Investigation

Process for Meaning
The Gray Step Illusion Inquiry

Inquiry Starter

• Explore the cards.
• Raise questions
Inquiry Starter

• engage student interest
• generate questions
• define a domain of study
• introduce materials and phenomena
The Gray Step Illusion Inquiry

Inquiry Starter
- Explore the cards.
- What questions do you have?

Focused Investigation
- With a partner, select a question to investigate further.
- Investigate
- Give thinking tool
Investigation

- Interact with materials
- Plan and carry out investigations
- Make observations
- Ask questions
- Talk to each other to share observations and ideas
- Propose explanations
- Make predictions and test them
- Revisit questions and explanations in light of new observations
- Record and represent thinking through writing and drawing
The Gray Step Illusion Inquiry

Inquiry Starter
• Explore the cards.
• What questions do you have?

Focused Investigation
• With a partner, select a question to investigate further.
• Investigate
• Give thinking tool

Process for Meaning
• Share results
• Synthesize results
Process for Meaning

- Share results, conclusion, and evidence to come to an understanding of the phenomena and concepts involved in that phenomena.

- Connect the results to major science concepts and their applications.
Transformative Inquiry Experience

• It is engaging. It makes you want to learn.

• You build on your own interests and questions.
  – It brings you to the edge of your knowledge.

• Knowledge learned is “active,” not “inert.”

• There is a strong affective response to learning this way.

• “You want your students to experience this kind of learning.”
How Do We Know It Worked?

Considering all of the influence on your teaching practice, how influential was this conference?

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<th>Influence Level</th>
<th>Percentage</th>
<th>Number</th>
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<tr>
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<td>10</td>
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<tr>
<td>very influential</td>
<td>57%</td>
<td>16</td>
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To what extent will your experience at this conference impact how you proceed with your teaching activities?

<table>
<thead>
<tr>
<th>Impact Level</th>
<th>Percentage</th>
<th>Number</th>
</tr>
</thead>
<tbody>
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<tr>
<td>a little impact</td>
<td>3%</td>
<td>1</td>
</tr>
<tr>
<td>some impact</td>
<td>29%</td>
<td>8</td>
</tr>
<tr>
<td>a lot of impact</td>
<td>68%</td>
<td>19</td>
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How Do We Know It Worked?

CfAO students use of inquiry in their teaching.
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• “Science Community Posters” displayed from 5-6 at reception
Creating Inquiry Activities: Setting Goals for Both Process and Content

Lynne Raschke
Graduate Student
Department of Astronomy and Astrophysics
University of California – Santa Cruz
and
The Center for Adaptive Optics
Creating an Inquiry Experience: Goals

One of the most important things we learned from the Maui workshop was that in order for an inquiry activity to be truly successful, significant time must be spent developing both content and process goals for the activity.

Content goals: the important concepts you want them to walk away with

Process goals: the skills you want them to learn or practice
Setting Goals for Diverse Groups

• COSMOS: 7 California high schools
  recent 9\textsuperscript{th} graders to high school graduates

• Orientation: variety of majors
  several community colleges and universities
  freshmen to juniors.

• As a result, in both
  groups the \textbf{background preparation in science –
  specifically in physics material} – varied widely
  among the students.
Example: COSMOS Optics Inquiry

Scott Severson and I co-taught the lectures and labs for the astronomy course in the COSMOS summer program. Because of our students’ varied educational backgrounds, we wanted to give them all an introduction or re-introduction to basic concepts in optics during the first week of COSMOS. We also wanted them to learn and practice certain practical skills.

But how do you set goals for a group of students with such a diverse set of background preparation and skills?
Setting Process Goals

Our process goals were the skills we wanted our students to learn and practice throughout the COSMOS program, including:

• exploring and investigating phenomena
• formulating good questions
• generating hypotheses and testing them
• presenting results and speaking in front of peers
Setting Content Goals: A More Difficult Challenge

How do we address the wide variety in prior optics knowledge our students would have?

At what level do we set our content goals?

What concepts are too basic? Which are too challenging?

Our realization: *It depends on the student!!!*

But luckily, since inquiry is *learner-driven* it is possible to engage and challenge at each student’s level.
Setting Content Goals: Addressing the Challenge

To address this challenge, we created a set of 3-tiered content goals:

- **Tier 1**: concepts that all students would learn
  Example - the different way convex and concave lenses affect beams of light

- **Tier 2**: concepts that many of the students would learn
  Example - how convex lenses form images and why they are inverted.

- **Tier 3**: concepts that would challenge those students with the most background in optics
  Example – experimental derivation of the law of reflection
Creating Inquiry Activities: Setting Goals

Setting our goals was an extremely important first step towards our successful inquiry activities. It set the stage for all of the design and implementation that followed.

In the COSMOS optics inquiry, using 3-tiered content goals allowed us to set appropriate goals for all of the students in our class.

Next, Seth Hornstein will discuss how we designed inquiry starting points to motivate investigations which would address these goals.
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Creating Inquiry Activities: Design and Preparation

Seth Hornstein
Graduate Student
University of California, Los Angeles
Design Starting Points

• Content Goals: 3 Main Questions
  – How is color related to temperature?
  – What causes emission/absorption lines?
  – Why do objects look different through different filters?

• Hurdles
  – Limited Space
    • 1 Lab Room
    • 15 Students
  – Limited Time
    • Originally started with 2 hours reserved for this activity
    • Ended up reworking schedule to allow for 3 hours.
Developing Questions

• Why reinvent the wheel? Build from previous experience!
  – Red-Blue Box
    • Educational tool used to demonstrate color temperature.
  – Spectrographs
    • Instruments purchased/used for undergraduate Intro to Astronomy course
  – Ishihara Tests
    • Tool used to detect color blindness

• Brainstorming
  – All possible variations of the original questions
  – New topics that could branch off from the original questions
  – Minimize QWWWNDWATTs
Materials

• Sources
  – Physics labs
    • UCLA
    • UCSC
    • UCB
  – Astronomy Teaching Resources
  – Office Depot
Outcome

- **Success!!**
  - More questions came up than we had originally planned.
    - Basic questions
    - Difficult questions
  - Everyone was able to explore their own questions.
- **Post Orientation Survey**
  - 71.4% listed the activity as “Excellent” in usefulness
  - 57.1% listed the activity as “Excellent” in quality
    - Refine introduction?
    - Or were we more successful than we thought?
- Facilitation was a lot more difficult than we expected.
  - How do you help them out without giving them the answer or pushing them in a specific direction???
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Facilitating the Inquiry Experience

Anne Metevier
Dept. of Astronomy & Astrophysics
UC Santa Cruz
Center for Adaptive Optics
Facilitation Goals

• Participants have full inquiry experience

• Students learn content through their own investigation

• Provide a positive learning experience!
Preparation for Facilitation

• Practice!
  - Be creative
  - Be flexible

• Try activity yourself!
  - Watch others try it

• Determine logistics
  - “zone defense”
Social Interactions

- **Group dynamics**
  - Is group getting along?
  - Are there competing ideas?
  - Is one person taking over?

- **Diagnosis**
  - Continuous assessment
  - Observe, then ask

- **Intervention**
  - Simplify
  - Encourage modeling

Respect the investigators!
Stages of Facilitation

• Early: students design investigation
  – Focus, clarify question
  – Help with materials and workspace

• Middle: students carry out investigation
  – Encourage and validate
  – Intervene if “stuck”

• Late: students come to conclusions
  – Ask students to explain “why”
  – Students prepare presentations
Synthesis: Making Meaning

• Students share results
  – Ask clarifying questions

• Synthesize results
  – Present learning goals
  – Relate to each group’s conclusions
  – Stress ideas that challenge students’ prior conceptions
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Experiences with Inquiry: Developing strategies to incorporate elements of inquiry into teaching

Jason Porter
Advisor: David R. Williams
The Institute of Optics and Center for Visual Science
University of Rochester
Center for Adaptive Optics
Stages in full inquiry investigations

1. Students are engaged with a scientific question, event, or phenomenon.

2. Students are free to explore their ideas through hands-on experiences where they can create and test their self-developed hypotheses.

3. Students analyze and interpret their data to synthesize their ideas and formulate working models.

4. Students connect what they have learned to their own ideas.

5. Students extend, apply and evaluate what they have learned to future tasks and problems.
Scenario - How to incorporate inquiry?

• “Lecture” Goals:
  – Teach students about clinical vision to prepare them for a field trip to the UC Berkeley School of Optometry.

• Topics that needed to be discussed:
  – Reasons for basic refractive errors in the eye
  – How to correct these errors: glasses, contact lenses, laser refractive surgery (LASIK)
  – Introduction to diagnostic tools used during eye exams and the information they provide to clinicians
  – Pathology - Ocular and Retinal Diseases and their treatments
  – Careers in Vision

• Allotted Teaching Time:  **ONLY 2 Hours 30 Minutes!**
  ⇒ Does this limit how and what I can teach?
Engaging students in scientific questions

• Time spent on activity: ~ 50 minutes
• Task: Classify each group of lenses and observe any trends or patterns within each group.

• Materials provided to group (5 students per group):
  – Projector with slide focused at infinity
  – Piece of white cardboard serving as a moveable screen
  – Meter stick
  – Different sets and powers of correcting lenses
Facilitating exploration

- Class had already been taught some optics and lens properties.

- I observed that the groups were struggling a bit in the beginning.
  - Pulled them back together to remind them of some of the basic properties of lenses and provide some possible directions.
  - The students were then set free once again.

- “Challenge Activity” was successful in eliciting group activity and discovery
  - Still wish we had a little bit more time to explore!
Lessons learned from inquiry experiences

1. It is important and valuable to engage the students in the learning process.
   - Students can perform their own exploration.
   - Students can formulate and test their own theories for the phenomena they are observing.

2. During Inquiry Based activities, it is very important to monitor student/group progress and interact when appropriate. Are the students developing and testing their ideas or do they need some “suggestions” to build momentum?

3. Teachers can learn from the students:
   - Students can make new, unexpected observations or can demonstrate a different approach when completing their task.
   - Students can provide input on what activities were exciting and helped them to learn the material.
Lessons learned from inquiry experiences

4. Even though full inquiry experiences are highly valuable, a great deal can be gained by incorporating elements of inquiry into teaching.
   • It is not practical, feasible or necessary to perform a full investigation in every scenario.
   • Students can still be involved in the questioning, discovery and learning of basic concepts.
   • Activities can still be designed to facilitate the students abilities to connect these basic concepts to real world applications.

⇒ UCB School of Optometry field trip provided valuable feedback.
Summary

• Workshop has become the cornerstone CfAO EHR project:
  – We are teaching science through inquiry
  – Graduate students and postdocs are excited about education (practice and research)
  – The sense of community is much stronger
  – Collaboration and cross-disciplinary interactions have increased.

• Next steps:
  – Add assessment strand to workshop
  – Case studies and disseminate model
Science Community Posters

- Posters aimed at high school science teachers.

- Develops skills to communicate research to different audiences.

- Expanded attendees beyond teachers to broadly include the scientific, technical and educational communities.

- Facilitates cross-disciplinary communication.

On display today at CfAO between 5 – 6 PM!