

**CfAO Educational Activities**  
**Prepared by Tiffany Glassman, May 2002**  
**CfAO Mini-Grant Project**

Below is a list of activities that had been developed for various CfAO projects prior to the Maui Educational Meeting in May 2002. I compiled this list in order to explore which activities that the center was already using would be most appropriate to be turned into inquiry-based activities by the Maui workshop participants.

I evaluated the activities based on how easy it is to jump right in with the materials, the questions that could be raised, the ability to further explore these questions with the given materials, and the concepts that could be taught. I found a wide range of applicability to the inquiry-based teaching method. Inquiry activities were successfully developed from these materials and tested during the CfAO internship orientation and the Stars, Sight and Science program in 2002.

**I. VARIOUS BASIC OPTICAL ELEMENTS THAT CAN BE PLAYED WITH IN ANY COMBINATION: (Just optics, so both astronomy and vision science)**

A. Table-top optics (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: Concave and convex lenses and mirrors on moving stages, polarizing filters, laser with single/double slit diffraction. Bought from [this online store](#). Might be able to borrow from local sources in Hawaii, most likely will have just one or a few of each item. Can play with various parts in MANY ways, lots of physical phenomena to explore and engage.
- Question raised: Why does this optical component behave this way? E.g. what about a diffraction grating spreads light out by colors? Why does light have colors when spread out but not before that? Why is light polarized? Why are images reversed? ...
- Concepts Taught: Image formation, ray model of light, colors of light, focusing, polarized light (wave model of light), diffraction (wave model of light), many more...
- Usefulness for Inquiry: Generates good questions that relate to MANY different concepts, questions are generative, can be followed up with same materials, but too large of a scale – need to limit materials so that questions all cover overlapping concepts. Probably best bet for inquiry, but need to use just part of all the optics components
- Usefulness for Lecture/Demo: Could easily demonstrate many of the relevant phenomena

B. F-box table-top optics setup

([Arion et. al. Carthage College](#))

- Materials/ Hands-On Nature: Fairly cheap (?), only one (?) but multiple parts, would have to ship it. Can play with it, a fair amount of phenomena to explore.
- Question raised: Why does the F flip? Can I make it not flip? Where is the focus for different lenses?, What is the relationship between focal length, magnification, etc.? What happens if part of the lens is masked out?
- Concepts Taught: Light, images, focusing, why images flip, lenses, etc.

- Usefulness for Inquiry: Generates good questions that relate to a small set of concepts, questions are generative, can be followed up with same materials
  - Usefulness for Lecture/Demo: Could easily demonstrate many of the relevant phenomena
- C. Emission lamps, diffraction gratings, and line identification (used for Stars, Sight and Science)
- Materials/ Hands-On Nature: Charts of emission lines, discharge tubes, diffraction gratings (plus more of this type of thing from Sasha's part). Expensive, would need to ship it, probably only one set of lamps, might need better diffraction gratings than 'rainbow glasses'. Can play with it, lots of phenomena to explore.
  - Question raised: How are the lines we see made? What material does each correspond to? How does diffraction grating let us see lines? Are there lines in all spectra? How does the lamp make the gas emit lines? What would I see if I looked at this object with the diffraction grating?...
  - Concepts Taught: Spectral lines correspond to certain materials, blackbody color is different than spectral lines and relates to temperature, diffraction grating properties, lamp properties (i.e. heating up gas makes it emit light), how astronomers can know what objects in space are made of
  - Usefulness for Inquiry: Generates good questions that relate to a fairly limited range of concepts, questions are generative, pretty easy to follow up with same materials — look at different light sources (sun, incandescent bulb, fluorescent bulb, continuum source behind cold emission lamp (?), colored paper under different light sources)
  - Usefulness for Lecture/Demo: Could easily demonstrate many of the relevant phenomena

## **II. SHACK-HARTMANN WAVEFRONT SENSOR (some basic AO optics stuff too)**

- A. Vision science wavefront (WF) sensor ([Roorda, University of Houston; Steinbring, UCSC](#))
- Materials/ Hands-On Nature: Only one and would need to ship it. Two more to be built in 2002. Can play with instrument a little, can play with results more, not too many phenomena to explore directly with this set-up.
  - Question raised: How does the apparatus work? What is the path and purpose of the laser? What happens inside my eye? What does the picture that it makes mean? Can you diagnose my vision with it? How does the wavefront sensor work?
  - Concepts Taught: Wavefront distortions in eye, Shack-Hartmann wavefront sensor, Zernike modes of decomposing distortions and how they relate to vision
  - Usefulness for Inquiry: Generates good questions that relate to a few different areas but not totally unlimited, questions are generative, can follow up if we bring in extra materials, e.g.:
    - To follow up how WF sensor works use Doug's WF sensor mockup
    - To follow up what modes mean and how they differ between people, compare the printouts for each person (or first 2 modes) with how bad their vision is,

- To follow up what modes mean, use camera lens (i.e. Jason's suggestion) to generate aberrations and/or show pictures of what different Zernike modes look like
  - To follow up on path of laser and how machine actually works, they could play with the setup itself
- Usefulness for Lecture/Demo: Not too good for demo, it only does so much

#### B. [Shack-Hartmann Demonstration](#)

- Materials/ Hands-On Nature: Fairly cheap (?), only one (?), would have to ship it. Can play with it a little but only really one thing to do with it, and it needs to be explained.
- Question raised: Why are spots displaced? By how much in different situations? How does the movement of the spots relate to the distortion of the image as a whole?
- Concepts Taught: Wavefront distortion, SH WF sensor basics, some geometric optics
- Usefulness for Inquiry: Generates some questions but they relate to too limited a range of concepts, questions are NOT generative, can be followed up with same materials, but need explanation from teacher, more useful as follow up for questions raised elsewhere
- Usefulness for Lecture/Demo: Could demonstrate some phenomena, not too great

### III. TELESCOPE DESIGN (Astronomy)

#### A. Amateur Telescopes with different designs that can be handled (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: Expensive and probably only one of each, might be able to borrow from local groups. Can play with them, some phenomena to explore, fairly engaging.
- Question raised: How does the telescope make an image of an object? What does this mirror do? What is the path of the light through the system?
- Concepts Taught: Geometrical optics, image formation, telescope design, telescopes as light buckets.
- Usefulness for Inquiry: Generates good questions that relate to a fairly limited range of concepts, questions are generative, can be followed up with same materials (e.g. what happens if I block part of the entrance, what are advantages of different designs, what happens if mirror is bigger or smaller)
- Usefulness for Lecture/Demo: Hard to demonstrate, really need to get up close and look at them

#### B. Telescope making kits (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: Cheap (?), portable, many available. Can play with it, but need a lot of instruction at the beginning to get the kit put together
- Question raised: Same as amateur telescopes

- Concepts Taught: Same as amateur telescopes
- Usefulness for Inquiry: Mostly same as amateur telescopes. Easier to change things about telescope and see effects, less worried about hurting telescope. Could be used to give preliminary understanding of telescope design before exploration begins using real telescopes.
- Usefulness for Lecture/Demo: Could demonstrate putting kit together and showing that it works, but not too exciting

#### IV. VARIOUS (Vision Science)

##### A. Optical illusion Java (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: [On website](#). Includes Ponzo illusion (2 bars of same size look different when placed on top of receding railroad tracks), Muller/Lyer illusion (2 lines of same length look different when they have arrow heads or inverted arrow heads on the ends), and Poggendorf illusion (two halves of a line look like their not lined up when the middle is covered by a bar at a 45° angle). Can play with it, a bunch of parameters can be changed to see how they affect the illusion
- Question raised: How does changing this affect what I perceive? Why do I see an illusion at all? How does it relate to the way we see/think?
- Concepts Taught: Eye/Brain system and how we process visual stimuli? But I don't know the science, so I'm not sure.
- Usefulness for Inquiry: Seems like it generates good questions that relate to a few concepts, questions are NOT very generative (?), not easy to follow up on (although they might be easier than I think, I don't actually know why the brain sees these illusions)
- Usefulness for Lecture/Demo: Could demonstrate some illusions and show e.g. that the lines are the same length, not too great

##### B. Color Vision - colorimeter, CIE diagram (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: Expensive, only one (?). It's a measuring device, so can use it to play with anything around you with color
- Question raised: What coordinates do different colors I see have? Are different types of objects in different parts of the graph? Is there any such thing as a pure color? What can I vary about objects I look at that will change their color? Change lighting, man-made vs. natural, reflected vs. generated light, could look at an emission lamp – should be pure color (?)
- Concepts Taught: What does color mean, what affects color, how do we perceive color
- Usefulness for Inquiry: Generates good questions that relate to a small set of concepts, questions are NOT very generative, can easily be followed up with just making more measurements with colorimeter but doesn't go too far or get to really fundamental concepts
- Usefulness for Lecture/Demo: Not good for demo, most you could do is to show diagram and how instrument works

## **V. PROBABLY NOT APPROPRIATE FOR INQUIRY (AS CURRENTLY USED OR DESCRIBED)**

### **A. Astronomy Picture Identification (used for Stars, Sight and Science)**

- Materials/ Hands-On Nature: Cheap to make many copies, bring them with us. Can play with it all they want and easy to jump right in, BUT without any background they might not be engaged
- Question raised: What is this object? What's going on in e.g. this dark patch? What's the difference between one object and the next? How can I figure out what's going on in this object based on what I see in the photo? Is this really the color of the object and why?
- Concepts Taught: Sizes of astronomical objects, how different colors arise (dust, stars, reflection, lines, etc.), what do astronomers do next once they have a picture,
- Usefulness for Inquiry: Generates good questions that relate to a good range of concepts in several directions, questions are generative, BUT would be VERY hard to follow up and too open ended
- Usefulness for Lecture/Demo: Could easily give a lecture and point out the characteristics of each photo, but not really a demo

### **B. [Color Vision Demonstration](#)**

- Materials/ Hands-On Nature: Fairly cheap (?), only one (?), would have to ship it. Can play with it, but need someone to show you how to use it, where to look, what you're supposed to see, etc.
- Question raised: Why do I see what I see? Do other people see different things? How does apparatus allow me to see this pattern?
- Concepts Taught: Color vision - different people have different vision depending on numbers/placement of receptors
- Usefulness for Inquiry: Generates some questions and engaging in terms of a cool phenomenon, but only relates to one thing, there's no place to go after that and you need to be told that it's your color vision you see, questions are NOT really generative. Not really suitable to follow up: could draw what you see and compare to others, but can't really figure out what's going on in eye from this, I don't think there is actually any connection between what you see here and how you perceive color (except maybe for color-blind people).
- Usefulness for Lecture/Demo: Not good for demo, each person needs to look through it, and not too much to say about it

### **C. Cows eye dissection**

- Materials/ Hands-On Nature: Cheap (?), is it transportable? Can play all they want but need supervision
- Question raised: What are these parts I see? What is their function?
- Concepts Taught: Lens makes image, retina detects light
- Usefulness for Inquiry: Generates good questions that relate to a small set of concepts, questions NOT very generative, hard to follow up (though other questions/ phenomena

might come up that I don't know about)

- Usefulness for Lecture/Demo: Could demonstrate a dissection and talk about the different parts

## **VI. NOT APPROPRIATE FOR INQUIRY (AS CURRENTLY USED OR DESCRIBED)**

### A. Model of Solar System components (used for Stars, Sight and Science)

- Materials/ Hands-On Nature: Cheap, easy to replicate, transportable. Can play with materials, but no interesting phenomena to engage and raise questions. The instructor must show how the analogy works and then there isn't any more
- Question raised: How big are other things in comparison? (Distance to other stars, galaxies, etc.)
- Concepts Taught: Size of solar system and many astronomical objects in general
- Usefulness for Inquiry: Doesn't generate many questions, NOT generative, no real way to follow up – just a model, not a physical phenomenon
- Usefulness for Lecture/Demo: This is really just a demo anyway, make model and talk about its components and what they correspond to

### B. [Tip-tilt corrector for telescopes](#)

- Materials/ Hands-On Nature: Expensive, only one, difficult to set up. Can't play with it, only does one thing
- Question raised: How does the WF sensor work? How does it know what to correct? How does it correct it? What good is correcting this? (i.e. what can you see better)?
- Concepts Taught: Wavefront sensing and basic tip-tilt correction
- Usefulness for Inquiry: Generates few questions (can't really play and create their own questions), NOT generative, no way to follow up – can't get inside box and see what is happening
- Usefulness for Lecture/Demo: Really is just a demo, but not too much to say with it, can show people difference between AO-on and AO-off modes, that's about it