This talk is a discussion of a first-pass attempt at applying inquiry ideas in a tricky content area.

I’m not selling anything. Whereas the IFI folks have thought about inquiry for years, I have tried this project once, with 3 students. So I have no grand conclusions about How This Should Be Done or anything like that. But I can highlight some important issues about the IFI inquiry design and how it might need to be modified to suit one’s needs.

If, after last Monday, you’re thinking that inquiry is pretty neat but would be really hard to do in your own field/teaching, I’m here to say that you might be right, and that’s ok.

My talk can be seen as one kind of response to Alex’s questions from last Monday: how do you do this in something more theoretical? Not hands-on? How does it look different?
**Context**

- The IFI examples of inquiry are hands-on, tabletop physics examples.
- CfAO folks who’ve been through the IFI workshops have successfully implemented their own hands-on, tabletop physics inquiries (optics, colors, etc).
- But: is it possible to stretch the model to other stuff?

IFI = Institute for Inquiry; CfAO = Center for Adaptive Optics
This is from the manual for the light & shadow inquiry that you went through last Monday. Notice the bold claim that what you saw in that activity can be applied to any topic.
"Exploring Galaxies" was a project, as we term them, for the CfAO’s cluster of COSMOS. COSMOS is the California State Summer School for Mathematics and Science (try to figure out how that acronym works), a 4-week program for high school students in which they reside and learn on a UC campus. COSMOS is divided into clusters of ~15 students apiece – students in a cluster take courses together. The CfAO’s cluster is "Stars, Sight, and Science" where we teach courses on astronomy, vision science, and the science process, respectively. Inquiry methods had already been applied (with great success) in the form of an optics inquiry that informs the students about the workings of telescopes.

In the last ~2 weeks of our cluster the students divide into projects and spend most of their time working on them. This is where the galaxies project comes in.

I didn’t particularly apply inquiry ideas to the first thread (taking our own data and using it) so I won’t discuss it.
I started working on this in earnest at the May 2003 CfAO Maui Professional Development Workshop, where we go through more IFI stuff similar to the "3 kinds of hands-on learning" and "light & shadow inquiry" that you’ve done. So this was the 2nd time I’d done those activities as I was in Ed286 at the time.

I led a design session where I laid out the kind of thing I wanted to do and many people helped me hammer out some of the problems and issues. During COSMOS itself, our cluster can have a nearly 1:1 responsible-adult-to-student ratio at times, so I had plenty of support.

The images at the bottom were produced by the students. Each image is a close-to-true-color composite made from B (blue), V (green), and R (red) filter images. On the left is M101, a face-on spiral galaxy of Hubble type Sc. In the center is M63, a not-quite-face-on spiral galaxy of Hubble type Sb. On the right is M102, an edge-on lenticular galaxy of Hubble type S0.
This is my interpretation of the IFI inquiry structure that you saw last Monday.
It didn’t take long designing the galaxies inquiry before I knew it couldn’t possibly look the same as the light & shadow inquiry. The content just doesn’t lend itself to long periods of self-driven messing around in an attempt to figure galaxies out for oneself.
HST=Hubble Space Telescope
This particular image is M31, our neighbor the Andromeda galaxy. It has two
satellite companions, the smaller one is M32 while the larger one is
NGC205.
Note the distinct gradient from yellow to blue as you go from the center to the
outskirts of M31.
I had students look at about a dozen images such as this one, and I had them
write down anything interested they noticed and/or wondered. I had thought
deeply about this activity. What to do if people asked the "wrong"
questions? But the more I thought about it: given any interesting
astronomical image, there are only a few sorts of questions you can ask:
Why is it bright here, dark there? Why is it this color here, that color there?
Why does/do the object(s) have this shape/arrangement? Because you only
have the image and not much else, the questions you can ask are somewhat
limited. So it is with "real" astronomers as well. So as it turns out it is pretty
difficult to ask a "wrong" question here. However that is not an invitation
for you to try – you’re clever and I’m sure you could do it.
These are more samples of the images I used, and samples of some questions generated by the students. For the curious, that’s M61 on the top and M51 ("the Whirlpool") on the bottom. I find that adults are much more interested in the names/designations of galaxies than students are. I think there’s something about that in *The Little Prince*, isn’t there?
An example of questions being generated at different levels, just like in the light & shadow inquiry. Some students were asking questions about the way the galaxies are, while others immediately jumped to how they got to be that way. In fact, simulations indicate that if a disk galaxy accretes a dwarf galaxy along its rotation axis then a configuration such as this is a likely outcome. So, a very insightful question.

That’s NGC6782.
Instead of throwing the students into the investigation phase directly, I had them go through a particular activity together so that I could assess their level of thinking about galaxies. In the activity they are given ~30 postage-stamp images of isolated galaxies and asked to classify/categorize them. They choose the criteria and number of categories.

A representative sample is shown above. The students chose a one-dimensional scheme that goes from yellow/round/smooth to blueish/spiral/lumpy in six discrete steps, plus one junk category of blue blobby galaxies. (In case you are wondering, this is pretty close to the traditional Hubble sequence of galaxy classification, one scheme used by astronomers.)

This activity was illuminating for me – for instance, I saw that not all the students understood how our particular viewing angle might affect the apparent shape of a galaxy (astronomers would call this viewing angle inclination).
The meat of the investigation.
First I had the students remind themselves of some of the things they’d seen in their previous COSMOS astronomy coursework: the basic components of a galaxy, and so on.
Many of the questions were about the colors of galaxies. I showed a demo (the red/blue box demo) that demonstrates that a bright light bulb is hotter and bluer while a dim light bulb is cooler and redder. I explained that stars are the same way. I carried them through a mini-lecture of how the hot blue stars don’t live all that long. Notice I did not explain why galaxy colors are the way they are, but I gave them the crucial information (which they couldn’t possibly be expected to figure out for themselves) about stellar evolution that should have allowed them to assemble a story about galaxy colors. This is a recurring theme in this particular inquiry: rather than the student figuring out how everything works, they instead figure out the causal chain or the narrative links between component pieces that are taught to them.
Also, there were a lot of great process skills being taught here. Example: how do you find reliable information on the web?
Note that in this inquiry there was much more 2nd-hand investigation (texts, the web, etc) rather than 1st-hand like in the light & shadow inquiry. This is related to Hoyt’s comment at the Exploratorium last week, about how at first he wondered: surely someone knows about this, why not just read something?

As I felt that the students could give me pretty good explanations about solitary, passively evolving galaxies, I pushed their questions to interactions between galaxies (there’d been some examples in the original images I’d shown them during the question phase).

Here finally is a part of the inquiry where the students can actually "mess around" with galaxies, just like in an IFI inquiry!
Obviously the light & shadow inquiry is hands-on while many science topics are not. Even in the high-school chemistry lab – in some sense the epitome of hands-on science – no one is actually playing around with valence electrons the way we played around with light bulbs at the Exploratorium. But connections can be made between the 1st-hand experience (the fluid in this beaker changed color or whatever) and the 2nd-hand description (bonds).

Light & shadow is a physics topic. But many sciences work differently from physics. Evolution/paleontology, cosmology, much geology, etc are all concerned with explaining a causal chain of history rather than the more general predictive power of physics, chemistry, etc. Yet, these more descriptive/narrative sciences often require the tools of physics/chemistry/whatever in order to "tell the story". Example: a typical educational path for an astronomer is to have a degree in physics before even beginning astronomy studies. Astronomy is a descriptive/narrative science where physics is used for all the key plot devices. In that sense it is an "expert" topic – but a novice can still get into the game of figuring out the story for him/herself if the physics-ish parts are simply given/explained to him/her.
An example of how Leo was putting together the narrative explanation of galaxies without needing to figure the physics out for himself. For instance, he did not need to know how we measure the masses of galaxies (an entire research program unto itself!) – he could just take as given that we know something about the masses of these things.

In the post-inquiry discussion last week, someone (Marina?) mentioned that it is gratifying at the end when you can explain the phenomenon yourself. I think something similar is going on here.

Back to Hoyt’s comment: I think you can combine the idea of "just go off and read about it" with inquiry – after all, isn’t that a part of a practicing scientist’s work? Here Leo has gone off and read something about galaxies, but unbeknownst to the textbook author, he had his own ideas which he was testing against the text. At the Exploratorium you can form an idea and then test it by experiment, but in astronomy we often do not have the luxury of being able to set up experiments. So you test your ideas against whatever information is out there.

Candice said last week: "Struggling to articulate your understanding clarifies that understanding." I think this principle is widely applicable.
Lessons

- "Do it like Barry does" is not a good goal – don't put square pegs in round holes.
- Abstract out the things about inquiry that are so compelling.
- Make better learning the goal – by whatever means necessary. If it ends up looking different than what you thought you wanted, maybe that's ok.
- Astronomy is hard.

Some lessons.

I'd set out to make something that looked like what the IFI does. When it became clear that my activity would look different, I was disappointed. I shouldn’t have been. Of course it will look different when the content, the setting, nearly everything about it is different.

Some important things about the IFI activity that I felt could be abstracted away and applied elsewhere: letting learning be driven by student questions; the importance of listening to student explanations as an assessment; letting students form their explanations – and re-form them – in their own words and out of their own conceptions rather than forcing them to have my understanding.

I am still not entirely satisfied. Astronomy is a tough topic. I’m sure other sciences suffer some of these same problems. You can take students through the zoo of astronomical objects and have them memorize facts about them, but how do you get them to understand some things about how the universe works, how those objects got to be as they are, etc? You could just explain it to them, but many studies have shown that lectures + reading is a poor strategy. Have to make the learning more active, less inert.

Remember that you are where you are (a practicing scientist) only because you are part of the minority that actually did well in lecture classes. We don’t expect every student to become an author yet we strive for literacy – likewise it should not be necessary for everyone to become a scientist just to get some science understanding.
Maybe galaxies is just a tough topic. There’s nothing simple about galaxies – if you look at the research literature it is heavily skewed towards galaxy evolution, cosmology, etc these days. Perhaps a different astronomy topic would work better.

I did this in isolation from others’ astronomy work. Maybe someone smarter than me has done something really cool.

"Data mining" is a term that comes up a lot these days in astronomy (maybe in your field too). This is what happens when data become so plentiful that you require computer database techniques to search for interesting stuff. Perhaps an inquiry on searching for correlations among quantities/properties could be devised – this could work for some kinds of students but I worry about getting too far removed from the phenomena themselves. Somehow you’d have to really connect the galaxies themselves (or whatever content you were doing) to the points on the plot.

No one (not even the IFI folks) says that inquiry is something that’s good in all (or maybe even most) situations. Maybe there is something better than inquiry for touch situations like this one. I just don’t know what it is.
Seven Principles for Learning with Understanding

- Learning with understanding is facilitated when new and existing knowledge is structured around the major concepts and principles of the discipline.
- Learners use what they already know to construct new understandings.
- Learning is facilitated through the use of metacognitive strategies that identify, monitor, and regulate cognitive processes.
- Learners have different strategies, approaches, patterns of abilities, and learning styles that are a function of the interaction between their heredity and their prior experiences.
- Learners’ motivation to learn and sense of self affects what is learned, how much is learned, and how much effort will be put into the learning process.
- The practices and activities in which people engage while learning shape what is learned.
- Learning is enhanced through socially supported interactions.