THE LIFE AND DEATH OF BOB (a.k.a. NGC 6397)
Some comments on the course featuring Bob

INTRODUCTION
A college-level stars and galaxies course for non-science majors covers a multitude of topics, including (but not limited to) the electromagnetic spectrum, emission, absorption, and continuous spectra, atomic physics (inasmuch as it explains emission and absorption spectra), temperature determinations (via Wien's Law and spectral types), the relationship between luminosity, temperature, and size (a.k.a. the Stefan-Boltzmann Law), the HR Diagram, gravity, star formation, nuclear fusion and stellar nucleosynthesis, stellar lifetime estimates, stellar old age and death (including red giants, novae, white dwarfs, planetary nebulae, supernovae, neutron stars, black holes), stellar systems (clusters, galaxies, morphological classifications, interacting galaxies), and cosmology.

Having said that, I believe that it is largely up to the professor which topics he or she wishes to emphasize and how. Since virtually every term that I listed above is foreign to my non-science majors when they first walk into the door, I feel that it is my job to link as many of these bizarre phenomena as possible to something already familiar to the students. Thus I rely heavily on in-class demonstrations using everyday objects and a single photo from the HST, namely the image of NGC 6397, which we lovingly call Bob. But these are simply anchors to which the students can return, educational breadcrumbs along the winding path of the semester.

THE APPEARANCE OF BOB
Bob shows up on the first day so that students can discuss with each other what they can tell just by looking at a photo. Right away we pounce on ingrained assumptions: Are stars that look brighter really closer? Can you tell anything about their motions (some will have had enough astronomy to believe that the redder looking stars are redshifted, thus moving away)? Ages? Sizes? We start small, edge our way into uncharted territory, and then return to the anchor of Bob. Then we get a bit farther out, only to relate the new information to Bob.

TEACHING METHODS WITH BOB
As the included Powerpoint presentations demonstrate, I use a variety of teaching methods in addition to the recurring Bob theme. While the use of Bob has not been specifically tested, the classroom environment includes many approaches that have been tested and shown to result in measurable gains in understanding. Among these are lecture tutorials (Prather et al; see slide show for complete reference), ranking tasks, and think-pair-share questions. There will be week-long stretches where we don't refer to Bob at all, but instead work to understand the fundamentals of, say, the electromagnetic spectrum. Assessment is both formal and informal. Lecture tutorials allow me to see in real time what concepts students are struggling with. Many times I have simply said, "Think about how this applies to Bob," and students immediately have an "aha!" moment. Other real-time checks on understanding come in the form of the think-pair-share questions and so-called one minute papers, in which students try to elucidate the clearest or the fuzziest point from that class.

Formal assessment consists of exams and homework sets (occasionally incorporating ranking tasks) that sometimes specifically ask about Bob. During the semester, I give 4 in-class exams and a final exam, all of which are multiple-choice due to large class size. Again, there are often questions that specifically refer to Bob. Some questions are simple, but several require students

to extend their understanding to a new situation. Case in point: An HR diagram for Bob is shown side-by-side with the HR diagram for the Pleiades. Students have studied Bob's HR diagram extensively, but then they must apply that knowledge to the new (and vastly different) diagram and make comparisons between the two.

Because of their sheer volume, it would not be feasible to include the "scripts" for the entire semester of Stars & Galaxies, or even just the classes that make use of Bob. My class is directed partially by the questions of my students, so from one semester to the next (and even from one class section to the next in the same semester), the structure and order of topics can be quite different. For these reasons, I hesitate to provide anything that resembles a lesson plan in this presentation for fear that it would appear rigid. However, I would be happy to engage in dialog with any educators who are interested in incorporating this idea in their own classroom.

CAN WE TRUST BOB?
Before fully embracing Bob, it's wise to ask,

> *"Is this approach <u>measurably</u> better than a more traditional, textbook-based approach?"*

Honestly I have no idea. When my university's "universe in a semester" class was split into two courses (Solar System and Stars & Galaxies), I adopted Bob as my go-to image primarily because it had features that I wanted to start my semester with. Specifically, it had stars with different colors, different apparent brightnesses, and different spacings, and students could easily list what they could and couldn't tell from the photo. It was not incredible foresight, but rather serendipity, that allowed Bob to become as ubiquitous as he did. I have never taught a full-semester stars and galaxies class any other way, nor have I attempted to determine whether my students exit the class with a better grasp of certain concepts than another professor's.

In short, the use of Bob is completely untested in terms of its potential gains. So why trust Bob? Because it *appears* that having this sort of anchor is beneficial. Many questions from students during class can ultimately be answered by having them reconsider what they know about Bob. For example, in a class that chooses light as the first topic to explore, students will learn within two or three classes that the orange-looking stars in Bob must be much larger than the white-looking stars *if they're the same distance away*. They arrive at this conclusion from their own explorations of incandescent bulbs on a dimmer switch. Within a week, they are constructing rudimentary HR diagrams with the help of Prather *et al's Lecture Tutorials in Introductory Astronomy*, so when we hit the topic of stellar evolution much later in the semester, they've already absorbed what a red giant is and what it is relative to a "normal" star. They can witness the evolutionary tracks by looking at Bob's HR diagram, see where the orange and white and blue stars are in luminosity-temperature space, and make the connections.

It *seems* that Bob provides continuity in what could very well be an overwhelming class. Moreover, students have fun naming Bob (it's not always Bob, by the way). They put the "fun" in Bob's funeral about 2/3 of the way through the semester, listing (accurately) the things we know about Bob and, more important, *how we know them*. For example, they will say they know the distance to Bob, and when pressed to explain how they know, a student will inevitably pipe up, "From parallax!" That student will then be admonished by others, who remember that Bob was too far away for our current technology to detect parallax. Then they will go on to explain spectroscopic parallax.

Yet, as dear as Bob is to me, I admit that this is not hard evidence that Bob can be trusted. It would be an interesting study for astronomy education research to compare this approach to more traditional approaches, and I welcome insights from such researchers. But for now, my only goal is to introduce others to the potential of using a single HST image as a recurring theme in a semester of stars and galaxies.