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Inspiring Exemplary Teaching and Learning: Perspectives on Teaching Academically Talented College Students

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A Companion Piece to

Teaching and Learning in Honors

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Introduction and Motivation

The goal of most introductory, non-major courses is to expose uninitiated students to a discipline for which they may not otherwise have a strong appreciation or interest. The aim can be realized through the dissemination of large quantities of knowledge that represent a broad sweep of information about the discipline or through the use of specialized research topics that allow students to conduct investigations in a mode of discovery similar to that used by professionals. Although the broad sweep approach exposes students to a vast sampling of knowledge, it is by necessity rooted in fact-based learning and is nearly devoid of the active discovery that inspires researchers in all fields. Alternately, a course based on specialized research topics can offer students an in-depth, active-learning environment, which, by necessity, must be narrower in scope. Research has shown, however, that active instructional environments that are learner centered, knowledge centered, and community centered are the most conducive to support learning (Bransford, Brown, & Cocking, 1999).

Which of the two approaches best initiates students to a discipline can be argued, and a decision depends in part on class size, student background knowledge, and the stated goals of the course. Within such constraints, an active-learning course offers students the chance to experience the discipline more fully and to gain a more systemic appreciation for an area of study. The demystification of what professionals actually do can lead to greater future interest while increasing students' confidence in their ability to interpret subject matter critically.

TTU Honors Integrated Science Laboratory

The Honors College at Texas Tech University offers several non-major, integrated science courses with laboratories. The courses are designed to expose students to various scientific disciplines and to the inter-connectedness across all fields of science. Team taught with Dr.

Ted Reid, the course that is the subject of this paper combined chemistry and genetics with physics and astronomy. In general, the students have a minimal science background or lack confidence in their own ability to do science. Students were surveyed the first day of class to find out how they felt about science in general. The majority (~ 75%) said they disliked science, offering various responses such as "I am science illiterate," "I am a right-hemisphere person," and "Science is nothing but a bunch of facts."

The physics/astronomy portion of the course was conducted during the second half of the fifteen-week term. The physics laboratory was designed to promote student investigation through research into a topic that was exciting and that contained meaningful physics principles. There were three primary goals for the lab:

- Allow students to discover that real science is about exploration and that facts are just the final outcome of doing science.
- Demystify science by empowering students with scientific self-confidence through student-generated investigations.
- Design a laboratory that is adaptable across the huge diversity of student background knowledge by allowing students to choose investigations that challenge them at their particular level of understanding.

The overlying theme of the laboratory was investigating claims made by the Fox Network's television special *Conspiracy Theory: Did We Land on the Moon?* (2001). The special presented interviews with advocates of the theory that the NASA-manned lunar landings had been faked to cover up NASA's inability to send humans to the moon. Throughout, the program presented scientific evidence that purported to prove the landings had been faked. The Integrated Science students watched the special and were asked to take notes on all physical claims presented by the proponents of the moon hoax theory. They then chose several arguments to investigate in detail. Their queries required them to design, conduct, and analyze their own experiment and reach a conclusion based on how well their data confirmed or contradicted the claim in the show. Students were also required to keep a journal throughout the course to document all developments in their investigation.

For the first three weeks, students participated in benchmark laboratories that explored the relationship between motion and time by investigating position, velocity, and acceleration, using sonic motion detectors and VideoPoint probeware. (VideoPoint is commercially available screen capture software that allows two-dimensional analysis

of digital video.) The benchmark investigations were open-ended labs that allowed students to devise their own methods for setting up the experiment, interpreting the data, and estimating uncertainty and error. These lessons not only gave students important background information for studying aspects of motion but also prepared them to design and conduct experiments for their research project.

The Moon Hoax Project

As mentioned previously, the first physics lab began by showing students *Conspiracy Theory: Did We Land on the Moon?* (2001), the Fox television special. This special made a forceful case that the manned lunar landings by the United States in the late 1960s and early 1970s were a hoax. The program backed up each argument with physical explanations that appeared to support the hoax. The special gave virtually no counterclaims to those of the hoax proponents. Although the program's narrator frequently told viewers to "weigh the evidence for themselves," the one-sided presentation style made this invitation a virtual impossibility for viewers who were uninitiated in the subject matter. An example is the claim that the astronauts were not on the moon because in every lunar photograph where the dark sky could be seen, no stars appeared in the photos. Lunar photographs were shown, revealing the absence, and viewers were told that the absence was contradictory to the fact that on the airless moon, stars can be seen even when the sun is in the sky. The assertion was, therefore, cited as evidence that the photographs were not taken on the moon.

Students were required to watch the video and take detailed notes about various claims made in the special. Afterward, students were asked to consider which of the contentions they would like to investigate and to consider how they might design an experiment to test each statement. The various claims, which are detailed in the following section, required the students to consider, investigate, and master physical principles of motion, optics, and geometric perspective. In other words, students had to weigh the evidence for themselves.

Before being shown the video, the students were asked the following survey questions:

- How many of you would say you are confident that we landed humans on the moon?
- How many of you would say that you are sceptical about the authenticity of the lunar landings?

When asked these questions prior to viewing the video, ~50% of the students said that they were confident that humans had gone to the moon. The rest of the class had no opinion on the matter. Most of the "no opinion" students said that they had never considered the question and knew very little about the moon landings. After watching the video, students responded to the same two questions with a very different outcome. Of the nineteen students who watched the video, seventeen expressed scepticism about the moon landings.

An introductory research activity initiated students into the project they were about to conduct. All students tested the first claim made in the hoax video by Bill Kaysing, which was that the film footage of astronauts on the moon was actually shot in a film studio on Earth. Part of the proof offered in the video was the absence of stars in any of the lunar photographs: "Kaysing observed that despite the clarity of deep space the stars were missing from the black lunar sky" (qtd. in Moffet, 2001).

To test the assertion, students were asked to go out on a clear night and take a picture of a group member with the stars in the background. We suggested that they locate in a lighted area so that a clear picture of the group member could be made and in an area where the sky had a clear backdrop of stars in the image. The following week most students arrived at lab with concerns. Despite following the instructions and getting clear photographs of group members, none of them could find stars in any of their pictures. The following excerpts from a student journal express the thought process that went on during the activity:

> *Student #1: Journal Comments Prior to Activity*
> I understand that by doing this we will somehow come to a conclusion about whether or not stars would be visible in the photographs from the Moon in 1969. What I don't understand is exactly how this is possible. The photographs would be taken from two different planets with two different atmospheres. How can what happens here on Earth be related to what would happen on the Moon?
>
> *Student #1: Journal Entry Posterior to Activity*
> When I developed my film I was surprised by the results of my experiment. The result was a clear picture of me with a black sky behind me. The similarity between what happened to [sic] with pictures of me and the pictures of the astronauts led me to think about what is actually happening inside the camera.

The student went on to discuss information about shutter speed, which she found at Kodak.com, and then added: "If you get a camera to take a picture of a bright object, dim objects won't be captured on the film. I think it is safe to deem this experiment a success. From the information we gathered, we were able to discount the claims of the Moon Hoax video."

Summary of Select Projects

Students spent the final four weeks of the lab, choosing two claims to investigate, designing experiments, conducting the experiments, analyzing the results, and writing a final report about their research. In the final week, each group presented the results of its investigations. We should note that early into their investigations several groups discovered the website *badastronomy.com*, which refutes the claims made in the Fox television special. After the discovery, all groups were informed about the website and the information aided several groups in the design of their experiments.

Below is a short summary of each of the student investigations:

Investigation #1—
Same Lunar Backdrop Used in Different Apollo Pictures

In the video, the moon hoax advocates showed images where the lunar module seemed to be present in one image with a mountain backdrop but absent in another image with the exact same backdrop. The observation led to the claim that "the same artificial backdrop was used when shooting two entirely separate pictures." Students travelled outside of town and took images of a nearby shed against a distant backdrop of a house and barns. One image was taken with the shed in front of the backdrop and the second with the shed behind the students and out of the frame of the picture. The result of this small change in position had virtually no effect on the backdrop positioning. Students reported, "The two backgrounds differ less than one millimetre [on the image], which is smaller than the human eye can normally detect without the aid of a measuring device." They concluded that the hoax claim was incorrect.

Investigation #2—
Intersecting Shadows on the Moon

The hoax advocates declared that multiple light sources were used in the Apollo photographs despite the NASA contention that the sun was the only light source available. The hoax advocates pointed out that

shadows cast in the photographs do not appear to run parallel, and, therefore, they argued that multiple light sources were used in a film studio. The contention led hoax advocate Bart Sibrel to say, "Outside in sunlight shadows always run parallel with one another. So the shadows will never intersect" (qtd. in Moffet, 2001).

Two separate groups investigated Sibrel's claim by taking images of shadows cast by the sun in the early evening. The students drew lines from the source and along the shadow that was cast. Each group experimented with various viewing angles, source sizes, distance to sources, and changes in shadow perspective when viewed from a point above the plane of the ground. One group concluded, "Our data shows [sic] that you can get unparallel shadows in pictures on Earth where there is obviously only one light source."

Likewise, the second group found that representing "a three-dimensional scene in a two-dimensional image causes distortion because of a perspective. . . . But from an above perspective and greater linear distance the shadows do indeed look parallel and converge upon the sun." Both groups' final conclusions were that shadows cast by the sun do run parallel but viewed on a 2-D plane do not necessarily appear to run parallel.

Investigation #3—
Astronauts Moving in Earth's Gravity

Another claim made in the video was that the astronauts were filmed walking in a studio on Earth and the film speed was cut in half in order to make the astronauts appear to be in the moon's gravity. In the lunar hoax video, hoax proponents doubled the speed of astronaut film footage and concluded, "When the speed of the film is doubled, the astronauts appear to be running as if in Earth's gravity."

One group of students analyzed the motion of actual Apollo film footage, using the screen capture software VideoPoint, in order to determine the astronauts' acceleration due to gravity. To accomplish the investigation, Quicktime movies of astronauts on the lunar surface were imported into VideoPoint, and the astronauts' motion was analyzed by marking the change in position from frame to frame on the screen. The students' analysis of various astronaut motions, including hopping and jumping, found a consistent acceleration due to gravity of 1.44 m/s^2. From basic gravitational equations, the group calculated that on the moon, the acceleration due to gravity should be 1.63 m/s^2, while the apparent acceleration caused by slowing Earth-based film to half the speed would give an acceleration of 2.45 m/s^2. Although the lunar acceleration from the movies (1.44 m/s^2) is marginally smaller than the actu-

al lunar acceleration, it is very different from the factor expected if filmed on Earth and slowed by a factor of two, as claimed by the hoax video. The students' conclusion about the acceleration was as follows: "This is 6.759 times less than that on earth, which is close to the 1/6 proportion that is expected. . . . Upon doing so, the evidence was close enough to convince us that the movie was not slowed by a factor of two."

Other Investigations

Along with the previously noted experiments, student groups also researched several other claims from the video. One group investigated the allegation that NASA photographs had been tampered with since some crosshairs, which were crosses etched into the camera lens, in the photos appear to be behind the object in the photos. Students showed that such a phenomenon occurs when a bright white object saturates the film, filling in the cross and making it disappear in the image. The result gives the appearance that the object is covering the crosshair. Another group investigated the hoax claim that a second light source was needed to illuminate objects in shadows, which should not be visible if blocked from sunlight. Contrarily, the group showed that backscattering of sunlight off of a powdery surface, like that on the moon, can illuminate objects in shadow. Finally, a group investigated the question of lack of dust on the lunar module. The declaration in the moon hoax video was that the exhaust from the lunar lander should have caused the fine lunar dust to be elevated and set back down on the lander, covering it in dust. One group of students used a vacuum pump to evacuate a large beaker with flour at the bottom. By giving small bursts of air and watching how the flour responded, they concluded that the vacuum on the moon prevents dust from billowing as it does in the air on Earth and likewise would prevent dust from settling on the lander after it has descended.

Conclusions

Students met the goals of the physics portion of the Integrated Science Lab successfully. They determined a question to study, constructed an experimental design, and reached a clear conclusion based on data from that design. Students also expressed surprise and satisfaction in their ability to test claims from a major network's TV show, using simple principles and designs: they were able to use science to evaluate dramatic claims made in the popular media.

Finally, students conducted meaningful experiments that were correlated to their particular level of background experience, removing

most of the adverse effects created by the huge disparity in background knowledge often associated with an introductory course. In this particular lab, students who felt more comfortable with mathematics and physics chose quantitative projects that required more conceptually difficult computations, while students who were less able to conduct such analyses were able to design and analyze experiments that were more visual, yet every bit as compelling. The variety of approaches allowed all students to gain self-confidence in their abilities to question and explore rationally the claims made in the hoax video.

In the year since first offering the course, we have modified our benchmark lessons to fit better the phenomena that are explored in students' investigations, giving students the tools to express results both qualitatively and quantitatively. The benchmark lessons ensure not only that all students learn physics but also that the lessons remain meaningful to the students since they have a direct impact on students' investigations.

In the survey at the end of the class, 100% of the students were highly sceptical of the claims made in the moon hoax video. Students also came away with a new appreciation for scientific research and the process of scientific discovery. The following is a final student journal entry:

> The Moon Hoax arguments of the movie were not solid because they were based on the wrong logic. They were logical for conditions on Earth but the Moon is a different story. However, the arguments are very misleading and I think people who do not take into consideration the different conditions on the Moon and Earth would buy into that. This . . . show[s] that critical thinking is crucial when analyzing the information that we are bombarded with every day. Without critically analyzing the information, people would believe in [false ideas]. By making us test an argument from the show, this class actually showed us how to approach any information—with skepticism.

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