Experiential Education on the Edge: SETI Activities for the College Classroom

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In a sophomore-level, interdisciplinary honors class, we introduced students to the Search for Extraterrestrial Intelligence through assigned readings, student presentations, classroom discussions, and multiple experiential activities. In this paper, we present four of these novel experiential activities. In the first, students suddenly find themselves trying to make contact with an unknown person who is simultaneously trying to contact them. The second is a course-long role-playing exercise patterned after a "first contact" simulation held annually at the CONTACT: Culture of the Imagination conferences. The third and fourth are parts of a unique final exam where students must respond as a group to two surreal encounters, one being a "2001"-style monolith that shows up, as in the film, entirely without warning or instructions. For the final, we also developed an assessment rubric appropriate for this kind of open-ended test. We conclude by discussing recommendations for implementing similar experiential education activities, both specifically and in spirit, in other classes.

Outline

INTRODUCTION

In the spring of 2012, the two of us—an astronomer and a philosopher—team-taught a sophomore honors

class entitled “Life in the Universe” at Elon University. This essay is an account of some of the more venturesome experiential education activities we created, of some of the (hopefully) useful insights we came to as a result, and, along the way, what may be the most awesome final exam in the history of final exams. Elon is a private university in North Carolina with approximately 5000 undergraduates. Each year, approximately 50 entering freshmen are selected to be in the Honors Fellows program. During the first two years, these students are split into two honors classes each semester. The sophomore-level honors classes are interdisciplinary in nature and team-taught by two professors.

There are many definitions of “team-teaching.” One model would be a single class section taught by multiple instructors in serial segments, with little interaction between the instructors (Davis 1995[5]). At the other end of the spectrum, in some team-taught courses, the instructors create the syllabus together, all take part in each class meeting, and regularly discuss the grades for assignments. We followed the latter model. Our class examined the likelihood that extra-terrestrial intelligent (ETI) civilizations exist. We also addressed philosophical questions surrounding the search (and potential discovery) of ETI civilizations. One of us (Weston), a professor of philosophy and environmental studies, highlighted the philosophical questions, consistently defended the view that ETIs are quite probable and likely widespread, and made a project of drawing out and emphasizing the relationship between humans and other-than-human minds generally, including other animals as well as possible ET aliens (Weston 1988[19]; 2012[21]). The other (Crider), an astronomy professor, presented the astronomical data, professed the more pessimistic stance that ETIs are extremely rare or likely to be very difficult to find, and gave special attention to the connection between our accelerating development of technology and our search for aliens.

The benefits of team-teaching are well documented (Letterman and Dugan 2004[10]). For us, one especially vital benefit was the vigorous and charged discussion in class, often with students in the room physically bracketed between instructors. The instructors' often sharply opposed and energetically defended viewpoints pushed students to develop and defend their own points of view. We approached the subject of ETI via three key themes to which we returned constantly in talks, papers, and class activities:

The Search for Extra-Terrestrial Intelligence [SETI]. Our discussions of SETI at the beginning of the semester were guided by our reading of the novel *Contact* by Sagan (1985; the 1997 film version was also assigned as an out-of-class viewing). While this is fictional account of a first contact with ETIs, it describes an encounter that mirrors the expectations of the astronomical community, and offers a great deal of social and philosophical commentary and fairly well-developed and engaging characters and plotline as well.

The Drake Equation. In preparation for an early SETI conference, astronomer Frank Drake made a quick list of the factors that would be necessary to know to calculate the number of ETIs in the Milky Way Galaxy (Drake and Sobel 2010[7]). These factors include the formation rate of stars, the likely fraction of stars with habitable planets, the likelihood of intelligent life emerging given appropriate conditions, and the estimated lifetime of a communicative civilization. The Drake equation provided an excellent backbone for the class, with many student talks discussing some aspect of astronomy or biology and considering how it affects the hypothetical number of ETIs in our galaxy according to Drake's framework.

The Fermi Paradox. During a lunchtime discussion with fellow physicists in 1950, Enrico Fermi suddenly realized that at least some ETIs should be much older and more advanced than us, and therefore should have had ample time to colonize the entire Milky Way Galaxy by now. Given that we have not yet had verified contact with an ETI, he asked his colleagues, “Where *is* everybody?” His conclusion was that they do not exist. However, there are many other possible solutions to “the Fermi paradox”. We explored these by reading *If the Universe Is Teeming with Aliens…. Where Is Everybody? Fifty Solutions to Fermi's Paradox and the Problem of Extraterrestrial Life* by Stephen Webb (2002)[18].

While other authors have noted that SETI provides excellent material for an undergraduate curriculum (Cain 1975[1]; Hobson 2001[9]), few have written about their implementation, with the exception of Slater (1999)[14]

who went only so far as to suggest having students install SETI@home on their computers. In our class, a bit more than half of the class assignments were traditional: 10% of the final grade was based on daily reading quizzes, another 10% on 15 min student presentations, and 30% on three papers following the themes described above. The remaining 40% of the student grade was based on experiential activities that were much less traditional. Those are the activities we detail here.

EXPERIENTIAL EDUCATION ACTIVITIES

Many authors have explored the impact of experiential education versus more traditional, lecture-based academic learning in astronomy classes (Straits and Wilker 2003[15], Thompson 2003[17], Francis 2005[8]; Crider 2011[4]). We distinguish *experiential education*, in which instructors create the experiences, from *experiential learning*, in which learners are usually self-guided. The Association for Experiential Education (2012) defines twelve principles for experiential education (see (note-1), six of which were integral in constructing our own activities:

- Experiential learning occurs when carefully chosen experiences are supported by reflection, critical analysis, and synthesis.
- Experiences are structured to require the learner to take initiative, make decisions and be accountable for results.
- Throughout the experiential learning process, the learner is actively engaged in posing questions, investigating, experimenting, being curious, solving problems, assuming responsibility, being creative, and constructing meaning.
- Learners are engaged intellectually, emotionally, socially, soulfully and/or physically. This involvement produces a perception that the learning task is authentic.
- The educator and learner may experience success, failure, adventure, risk-taking and uncertainty, because the outcomes of experience cannot totally be predicted.
- The educator's primary roles include setting suitable experiences, posing problems, setting boundaries, supporting learners, insuring physical and emotional safety, and facilitating the learning process.

Our purpose is not to debate about these principles. In this paper, we accept it as a given that experiential education, so conceived, is a valuable component of college education. Instead, our aim is to present four examples of experiential activities, as distinguished by the above principles, that worked particularly well in our class, thus both illustrating experiential education in action and hopefully also inspiring others to consider similar activities—similar at least in spirit—in their own classes.

One-day Class Activity: “Someone is Looking for You”

The SETI program faces several basic conceptual and practical obstacles, mostly deriving from not knowing how a totally alien civilization might attempt to contact us. Cocconi and Morrison's seminal paper on SETI in Nature (1959)[2] proposed that aliens would most likely use a 1420 MHz radio signal, since this requires relatively low power and is the natural frequency of the most abundant element in the Universe, hydrogen—a salient fact to any mind exploring the universe. To this day, as a consequence, the bulk of SETI is conducted with radio telescopes, though some other technologies are being tested (Davies 2010[6]). To give our students a sense of the difficulty in “selecting a channel” and “alert signal” for communication, Weston arranged for his

daughter, an undergraduate at Rice University in Texas, to attempt to contact the class beginning at a specified time during our class meeting. He did not, however, tell her the names of any students or anything specific about the class. At precisely the specified time, we told our class that "someone is looking for you" and that they should attempt to make contact. Just as in the Cocconi and Morrison model, our students needed to settle on a common medium and signal, using only the most general shared knowledge. In this case, our students knew only that

- Someone was looking for them at that very moment.
- The stranger was not nearby (contact was not going to be physical).
- The stranger knew the students were at Elon University.

While Cocconi and Morrison settled on radio as the best means of communication, our students quickly settled on an analogue appropriate for this particular task: social media. Working in groups of five or six, our students started searching the internet for any messages from the stranger. Within 25 min one of the groups had succeeded. Weston's daughter had, among other things, inserted her Facebook contact information in the first line of Elon University's Wikipedia page. Our students found it within 7 min of her posting it (and promptly removed the message so as not to vandalize Wikipedia). Even more amazing was that two other groups were very close to making contact and likely would have done so within a few minutes. One group was checking Elon University's online want ads for a relevant posting; Weston's daughter posted such an ad, but on Craigslist (that was next). Another group was calling up our family members, guessing that the "someone" might be one of our relatives, and would have soon dialed the right person.

This exercise aimed, in short, to put our students into a clear and specific analogue of the situation of humans trying to make contact with unknown aliens. We can only assume that they might be trying to contact us and that we share the observable universe. During the activity, a question became clear during the first 5 min of the exercise: why search for someone if you are not even certain they exist? When our students began their search, many did so half-heartedly. Some were convinced it was a trick of some sort. One student asked us outright if there was really someone out there. When we affirmed that there was, with a sufficiently believable tone, they renewed the search in earnest. Their early attitude toward this activity mirrors our own current SETI program. It is difficult to commit time and energy searching without *knowing* that there is someone out there to search for.

Our students' success with this activity, which seemed very unlikely before the fact, also gave us and our students confidence when faced with further seemingly impossible tasks. Of course, if they had not succeeded at making contact, we were prepared to draw out the lessons of that failure as well. Weston's daughter was prepared for a "debriefing" Skype conference either way—success or failure—to discuss various strategies. We loved the idea of actually being able to compare strategies, right after the exercise itself, and note the ways in which each side might have glanced by each other, made assumptions about the other that might have been unnecessarily limiting, etc. In that sense, failure might have been even more illuminating than success.

Semester-long Group Activity: Astronauts and Aliens

Around the same time we also launched a semester-long project with a team of "astronauts" planning a mission to a world created by a team of "aliens." Our inspiration here was the CONTACT: Cultures of the Imagination (COTI) conference held regularly in California. COTI includes a multiday, rolling workshop in which two teams independently construct alien worlds and then populate them with promising species, work out in detail what kinds of intelligent creatures and civilizations might arise on them, and then bring the two teams together to role-play a first contact situation. Our version of the COTI experience was slightly different

from the original: we had one team (including Weston) envision aliens and another (including Crider) imagine future human astronauts. Students self-selected into the two teams, each with approximately a dozen students. In a series of group-written papers, we asked each team to imagine and describe their worlds and individual roles. During the semester, we held occasional 15 min team meetings in two separate rooms at the end of class for the students to plan and speak with each other and one instructor; both groups also worked extensively outside of class. Neither students in the two groups nor the instructors talked with the other about this work throughout this process. As it would be in the real world, we knew nothing about each other until the moment of first contact arrived.

The alien team dubbed their planet Aurora and themselves Aurorans. They imagined a species of cat-sized, bug-like creatures that could be nourished either from photosynthesis (on their dorsal side) or from digesting decaying wood (on their ventral side). The Aurorans evolved two forms of communication: one simplistic language of audible whistles and another more complex language shared electrochemically through and with the trees they inhabited. As Auroran civilization developed, their dwellings and other structures, as well as art, were constructed by arborsculpture. They lived almost entirely in the middle canopy of dense forests on Aurora's equatorial islands, lands of hot (but of course to them equitable) climate, sometimes stormy, with wild and sometimes unpredictable tides and waves (due to Aurora's multiple suns and moons). In fact, it was through coming to aid the trees in coping with the arrhythmic waters that Aurora's dominant species evolved its close physical and chemical relationship with them. This interdependence with the trees also led Aurorans to develop a significantly slower pace of living, along with “tree mind” communication methods, that was difficult to perceive by humans. The students generated a wiki to describe the alien world à la the Pandorapedia written to support the 2011 movie, Avatar (see Note-2).

The human team developed their roles as slightly misguided scientists working for billionaire philanthropist-explorers, selecting one student as their Foundation President and another as their Mission Commander. They quickly adopted the moniker “KICK Astronauts.” Anticipating that the alien species and civilization would certainly be strange, possibly even undetectable, the KICK Astronaut team developed mission goals and protocols that would allow them to claim success with nearly any final outcomes.

1. 1.
   The (unlikely) primary goal for the KICK Astronaut characters was to find humanoid alien life forms.
2. 2.
   If they failed to find humanoid life forms, they planned next to search for and capture alien animal life forms that would be suitable as pets for humans.
3. 3.
   If no alien life was found, their final goal was to strip mine the planet with robotic equipment. (Curiously, this goal was written into their mission protocol weeks *before* James Cameron and several Google executives announced real plans to strip mine asteroids.)

In the final weeks of the class, we set aside one full class session (100 min) for the astronauts to attempt to contact the aliens as they approached the planet but before actually landing there. The KICK Astronaut team met in a computer-equipped office foyer that was designated as the command ship. The Aurorans met in the much larger classroom and a third faculty member went back and forth between the two rooms to relay appropriate information. For example, when the KICK Astronauts indicated to her that they were beaming a radio signal to the planet, she left the “command ship,” she proceeded up the stairs, waited, and then returned saying that there was no response. (Since the Aurorans had no radio receivers, either technological or biological, she had no need to convey any message.) However, when the astronauts launched an orbiting probe around the planet, she asked the Auroran team to provide a map of their world and indicated that one Auroran had noticed a bright light moving in the sky overhead.

On the second day, the KICK Astronaut team returned to their "command ship" (see Figure 1) while the Auroran team decorated the room to form their rainforestlike habitat, complete with plants, green crepe paper, in-the-round wall projections of drawings of their forests, and a soundtrack featuring panpipe and digeridoo music (see Figure 2). When the first "astronaut landing party" failed to discover intelligent life (as defined by their standards, of course), a second group was instructed to land on an adjacent island. A KICK Astronaut team member, observing the landing via a FaceTime video call from the "command ship" described first contact in the final mission report.

Fig 1.
Students role-playing a first contact experience between humans and aliens. These "KICK Astronauts" are in their command module remotely observing the progress of the Shuttle One team via a FaceTime video call as the team lands on the planet Aurora.
View first occurrence of Fig. 1 in article.

Fig 2.
Students role-playing a first contact experience between humans and aliens. These "Aurorans" (in the foreground) are gathered around a sacred fire in their tree dwelling as the human approaches (in the background).
View first occurrence of Fig. 2 in article.

Shuttle Two has landed on Island I. They appear to be in a lush, green forest. The Commander describes Island I as extremely hot. After some observation, debate, and attempts at contact command determined that Shuttle Two has discovered what we would classify as "pets." They are the size of a cat with hard shells and many legs. They are very loud creatures and seem to be whistling, making sounds that are musical in nature. [The KICK Foundation President] is satisfied with the discovery… All [of] the [crew] members on [Aurora] are directed to capture a pet to bring to the ship for experiments.

The KICK Astronaut team did indeed "capture a pet" and the Shuttle One crew brought this Auroran team member back to the command ship room for observation. As the Aurorans naturally did not have any way of understanding what the alien invaders were or what they wanted, their viewpoint of this event was very different. The Shuttle Two team discovered this on their return visit. The Aurorans described this disastrous encounter in their Aurorapedia:

[T]he strange creatures came back. This time, much more violently. They harmed many of our trees and were headed straight towards [our sacred tree] Anala.

As we do to protect our trees when they are harmed, we wanted the beings injuring the trees to disappear. Several of us pressed our [ventral] membranes against the creature that was closest to the fire. As it slowly disappeared, the other unknown creatures were nowhere to be found. We threw the remains of the creature into the ocean and began to forget this peculiar occurrence.

As instructors, this was exactly the sort of miscommunication and misunderstanding that we had hoped the students would experience. The KICK Astronauts saw themselves as explorers, not as alien abductors. The Aurorans saw themselves as a society, not as man-eating animals. Still, despite the cascading and self-reinforcing misunderstandings that already were setting in, some students worked to break through the

communication barrier. Back in the command ship room, a few members of the KICK Astronaut team noticed that their new "pet" was whistling in a peculiar fashion and was attracted to a plant that was in the room (see Figure 3). The student playing the ship doctor took a sincere interest in learning about the captured Auroran and wrote the following in his log:

Fig 3.
Students role-playing a first contact experience with aliens. These "KICK Astronauts" are conducting experiments on a captured "Auroran."
View first occurrence of Fig. 3 in article.

[The mission linguist] and I have been testing the Pet for days now, and we believe we have discovered the Pet's language for plant and for fire. To communicate "plant," the Pet emits a high-pitched, one note sound. For "fire," it emits a series of three notes, high pitched to low pitched. The Pet does not make any noise when we splash it with water, but it does retreat into the far corner, which shows its aversion to it. We hope this discovery will foster communication between the astronauts and the Pets in the next shuttle mission. If this communication fails, the Pets will be decidedly not humanoid; we will capture a few more for study and then leave the planet.

The KICK Astronaut students were naturally uneasy about returning to the planet after one of their teammates had been disintegrated. While they had agreed in advance that their characters would carry out the mission no matter what, the students were visibly anxious. The mission commander and some others argued that they should not be treating the Aurorans as animals after discovering they had a language, albeit primitive. Still, the inertia of the mission and the authority of their KICK Foundation President prevailed. The KICK Astronaut team eventually made a third and final landing on the planet to capture more "pets," using water to coax them out of their arboreal habitats and fire to lure them into a cage. When that plan failed, two KICK Astronaut students grabbed one of the Aurorans and pulled her out of the constructed habitat.

The students on the Auroran team decided that this event was momentous and bizarre enough that it would likely become a part of Auroran folklore. This was somewhat unexpected, although our class had earlier discussed the concept of paleocontact between spacefaring civilizations and primitive species put forward by Shklovsky and Sagan (1984)[13]. The Aurorans wrote:

One day, the moon Porthos was angry. … So on this day, in a bright point of light and anger, Porthos sent emissaries from her surface to carry out a terrible act of revenge. Her invaders brought chaos and destruction upon us, the peaceful and complacent tree-dwellers. They came in small groups and made noises in an attempt to confuse us and mask their true intent. While we at first attempted to protect our fire, we were soon lured by their strange noises. All of a sudden they swooped in and stole one of our own, a firekeeper. … When Porthos was again full and powerful in the sky, she sent a second, and then later a third group of emissaries. They came in much greater numbers than the first group. They seemed to be communicating with us, but before long they turned against us, taking two more of our own and hurting Anala herself. Before we could get over our shock, they had disappeared back into the sky, and Porthos seemed satisfied.

At the conclusion of the role-playing exercise, it was surprising (though perhaps it should not have been) how happy most of the students playing the KICK Astronauts were and how sad and angry the students playing the Aurorans were. One Auroran student refused to speak to the KICK Astronaut team after class. Even two days later, during a lengthy discussion of the experience, there were lingering emotions. One student reported that she felt so strongly that she wrote at length about her emotions in a private journal. Members of the

Auroran team accused the KICK Astronaut team of being overly hostile, beyond what would be expected of reasonable humans. The astronaut team admitted its actions seemed hostile from the viewpoint of the Aurorans but were in fact quite representative of human behavior. The Auroran students agreed, noting parallels between their experience and real life. They listed several examples: many exploring societies that have ill-fated encounters with less powerful ones (e.g., Spanish conquistadors and Native Americans), many scientists who conduct research on animals, and many humans, including those in this class, who have pets. Yet all of this was part of the learning too. The whole point of the COTI exercise, after all, is to put our students right inside the very situation they were studying. It is all very well to imagine that of course we would pick up on alien intelligence if there as any to be found, and that we would avoid, through sheer good will, the kinds of misadventures and cascading-to-lethal misunderstandings that so often emerged in previous human-to-human or human-to-other-than-human "contact" situations right here on Earth. In the event, however, this very class went quickly and enthusiastically down the very same road in our simulation. Thus our students enacted and experienced the same problematic dynamic from the inside: they were fully engaged "intellectually, emotionally, socially, soulfully, and [indeed] physically" (to cite our definition of experiential education) as well. They truly "inhabited the question" that our class put before them. In their course evaluations, many of the students cited this exercise as the single most powerful learning experience of the class.

The Final Exam

From the start we intended to create some sort of unique experience for the students' final exam, representative of the tone and material of the rest of the course. Originally, we planned to craft an apparently alien message for the students to decipher, akin to the message sent by the Arecibo telescope. A later plan was to show Stanley Kubrick's 1968 movie *2001: A Space Odyssey* during the 3 h final exam period and ask students to write their interpretation of the movie in the 40 min that remained. However, this seemed a short time to write, and (most importantly) a bit too conventional for this very unconventional class. However, it did inspire what we ultimately did for the final exam.

Part One: The Monolith

On the last day of class in the term— three days before the exam—we showed the students the first and last of the four acts of 2001. In the first act, *The Dawn of Man*, a large black monolith appears on Earth and sparks a tribe of primates to develop primitive bone weapons. This scene ends with the famous cut-scene of a bone-weapon spinning up in the air and then transforming into an orbiting space platform. In the final act, *Jupiter and Beyond the Infinite*, an astronaut approaches a similar, larger monolith orbiting Jupiter. His contact experience with this alien intelligence is totally surreal. We discussed the film a bit at the end of class, mostly highlighting Kubrick's "sixties" vision of alien contact and the film's suggestion that the development of human intelligence was sparked by intentional alien prompts.

Thus ended the regular class. We had given the class very few indications about the nature of the final exam except to say "Get a good night's sleep and show up on time." Students were uneasy with this, naturally, but on the whole they were willing to play along. We'd like to think it was because they were pretty sure that we had something up our sleeve and were confident that, like the other exercises in this class, it would be challenging but ultimately intriguing and do-able. (Trust matters!)

So the morning of the final exam finally arrived. Students showed up to find that the classroom door was closed and its window covered with paper. They sat outside in the hallway waiting for an instructor to open the door. When neither instructor had appeared by the exam start time, one student finally ventured to open

the door herself. She found the room to be almost completely empty. The familiar tables and chairs were nowhere to be seen. No instructors either. And in the center of the room was an 8-feet tall black monolith (see Figure 4).

Fig 4.
The Final Exam, Part One: Cue "Thus Spake Zarathustra". Students entered the classroom to find it completely empty except for an 8-feet tall black monolith akin to the one in the film *2001: A Space Odyssey*. Four cameras and microphones in each corner of the room recorded their responses.
View first occurrence of Fig. 4 in article.

In the corners of the room were four wireless microphones paired with the four permanently installed cameras for recording classes. While there was nothing written on the whiteboard at the front of the room, on the tray beneath it sat one black marker, four red markers, and nine green markers.

Neither instructor ever showed up nor could we be found in our offices. The aim was to make it as clear as possible that the students were on their own. Shortly after the exam was over, we heard fragmentary accounts of what happened from some of the students, but we only got the full story when we reviewed the videotape along with the audio recordings of the actual session. Initially the students buzzed around the room, having many small conversations about how to proceed. They posed for a group picture with the monolith and emailed it to one instructor. They also tried having every member of the class touch the monolith simultaneously. A few tipped the monolith to look underneath. A few others noticed the number of markers at the front of the rooms and (correctly) reasoned that it was a hidden message. After roughly 30 min of mild chaos, the group collectively agreed (incorrectly) that there must be another monolith (somewhat as in the film) and their first job was to find it. Multiple teams scouted the campus for a second monolith while one team stayed in the classroom to decipher the 1-4-9 marker message. While they had quickly noticed that this was 1^2, 2^2, and 3^2, there was considerable discussion about some additional hidden meaning based on the spacing of the markers. One student suggested that 1-4-9 translated to A-D-I and that might be a clue about the room of the second (nonexistent) monolith. Another tried to find a hidden raster image that could be constructed from number or positions of markers and erasers. This was an unexpected but appropriate response. Students had made a connection with the book *Contact* (Sagan 1985[12]), where the alien message is described as a palimpsest, with multiple messages included in various components of the radio signal; in class we had also looked at message in prime-number-ratio rasters in real signals such as the Arecibo message as well as in the novel. These students also started reading about the monolith on Wikipedia, searching for clues about what they should do next.

The student groups reconvened in the room 1 h after the start of the exam. Having failed to find a second monolith, they abandoned their search. Two students then tipped over the monolith and within minutes, the class had formed a circle around it, as if it were a very low conference table (see Figure 5).

Fig 5.
During the third 30 min, students used the monolith as a conference table and discussed how the monolith related to the class themes.
View first occurrence of Fig. 5 in article.

While the first 30 min of the exam was chaotic, during this 30 min block the class worked as a single unit discussing several topics. The discussion that ensued was both rich and relevant. Students explored the deepest and most open-ended themes of the class, framed the issues carefully and sharply, and listened to each other productively.

One student began, for example, by questioning science itself. “This class made me not believe in science,” she declared. Referring to the Drake Equation—much debated in the class—she argued: “[W]e could have an equation… [but] the equation could be useless. I do not understand how there can be this science where it is not real. There is no way they are ever going to be able to calculate [the correct solution to the Drake equation.]” She concluded that “Science is just, like, pulling things out of the sky.”

Others acknowledged the open-ended nature of the Drake Equation and much of the speculation about ETIs. Still, they argued, venturing guesses is how science works. And progress has been made; we are far better able to quantify some of the factors today than we were when Drake created the equation. “Science is not just equations,” one student concluded. “It is not just people making stuff up. It is people trying to examine the world in a systematized way.”

Another responded:

I love thinking about how throughout human history, it has always been evident that there are things that we had no perception of. That, I imagine most of the time, through science, we finally discovered. You know, forces of gravity, magnetism, and sub-atomic particles. Everything … that we had no idea existed, and then we found it, and it changed everything. I don't think that is going to change. So, there are so many things, I think, in our future that are going to come up that we have no perception of.

Our search for aliens, he concluded, may be one of those things, too.

Many students reflected on how the class had changed their perspective on humanity's place in the Universe, including one who said:

This class has just made me feel more insignificant…. Not like in a sad way. [T]he universe is just so big and I never really considered that before. [E]ven if there are other species out there, I still feel like we're probably very rare. [I]t just made me feel small. I look up at the sky, “Oh my God, there's so much stuff up there and how tiny am I?”

Another student had the opposite perspective:

I think alternatively it would make some people feel bigger because there's all this space and it's just [for?] us. We're the only ones. [W]e're not really insignificant because we are such a rarity.

Contesting this anthropocentrism in turn, and remembering the COTI experience, others argued that we already live in a co-inhabited and vast world. “I think it is interesting,” said one, “that we think of life as plants and animals but when you think of aliens, no one ever thinks of plants. Is a forest an alien civilization?” Especially, added another, “if it had any way of communicating with each other but not that we could perceive.” The open-endedness of contemporary SETI, some said, might extend even to such possibilities.

Especially intriguing to us as instructors were students' thoughts about the transformative impact of the class. One student asked a question that actually became a touchstone for our thinking about this very “exam.” “What were our characteristics at the beginning,” she asked, “and how has this class changed us to become … less of the babies and more of the adults?” Another asked more pointedly: “How would you all have reacted to this [i.e., the monolith] on the first day of class?” One said: “The first day of class, we all would have walked in and just said, ‘What the hell?’” Others responded by talking about how much more seriously they were now inclined to take the topic of ETIs in general; how much better informed they were about the current state of astrobiological investigation and indeed the Universe in general, and how comfortable with some of the philosophical questions it all raises. In general, one reported, “I feel a lot more accepting of my uncertainty…. A lot of us feel that.”

One student spoke to the very moment:

When they were telling us about the final [they said], "We promise you will remember this final probably more than any other final at Elon." I'll remember it. Not necessarily because of the fact that we figured it out but the fact that I walked into the room and there is a big, giant black box there. That is something you're going to remember and that experience, like, alters your perception of your four years in college.

Following this, a lovely theme emerged of the way that this very exam not only mirrored the course as a whole but also our situation with regard to potential ETIs. As one student summed it up:

If we were to find aliens sometime in the future, that is the unknown. That's what this [exam] is for us. It is the unknown. We don't know how to respond. There's no rules. There's no correct way to handle this. If we go out there and find aliens, that is exactly what it is going to be. It is going to be, "What do we do now? What are they expecting of us?"

When Weston first heard this comment (on the tape), his reaction was elated, saying "That's an 'A' moment right there!" Since we (the instructors) are the "they" of the last question, we note too that the question essentially puts *us* into the problem, too—as the metaphorical aliens.

To some extent, this conversation might have been honors students playing to the camera. Indeed, one student placed two of the microphones atop the monolith-turned-conference table. However, even if this was the case, we found that the students excelled in their ability to relate the monolith to the class themes. We also noted that they automatically worked on the monolith challenge as a group. No one proposed working on it separately. (It might actually have been good for them to have gone one step farther when they were talking in the circle—to have gone around the circle somewhat more deliberately so that everyone had a chance and expectation to say something. As it was, they began this, but in their excitement did not sustain it.)

As the conversation wound down, several of the students proposed moving the monolith outside. There were two articulated motives for this. One student had read on Wikipedia that in the movie "[n]ot long after the monolith is exposed to sunlight after excavation, it emits an extremely powerful burst of radio-frequency energy." Other students wanted to share the monolith with the rest of the campus. It is also possible that they were seeking closure with the monolith, and simply leaving as it was when they found it was not enough. (This mirrors the film, too: after finding the monolith on then Moon, humans almost immediately follow its signal to Jupiter.)

The base of the monolith contained four 30-pound cement blocks, meant to stabilize the monolith and deter the students from moving it. Nevertheless, they managed to slide the monolith out the door and, in time, down the stairs. They erected the monolith outside of the building just in time for the second part of their exam.

Part Two: Animal Planet

A recurring theme of human interaction with animals emerged during the semester. Weston had described how musicians lower guitar speakers and microphones into whale-inhabited waters in the Pacific Northwest to play music with orcas and other cetaceans. Crider had discussed how his cat makes notably different noises, all with different communicative intent. After the poor treatment of "animals" by the KICK Astronauts, students on both teams vowed that they themselves would not be so insensitive. This is something we decided to test in the last part of the final exam.

Exactly 2 h after the start of the exam, part two began. Two large white vans were parked along the street outside the classroom window and at the designated time, the horn honked. The students raced out of the building: "We're going on an adventure!" A man in dark sunglasses (later given the moniker "Van Man" by the students) met them at the first vehicle but said nothing. On the driver's seat of the second van sat a box with its keys, intended for one of our students who had a van license (though she did not know that we knew this). Once the students were on board, the Van Man slowly led them to a house roughly two miles from the campus. The students exited the vehicles, approached the house and rang the doorbell. Suddenly, both garage

doors opened. They hastily went into the garage and through its back door into a large, enclosed backyard. They were greeted at the door by three hens. In the center of the yard was a buffet table (see Figure 6) with the following items:

- a pitcher of water,
- a bowl of sesame seeds,
- clear glass drinking and eating containers of various shapes,
- five cheese pizzas,
- one barbeque chicken pizza.

Fig 6.
The second part of the final exam, later dubbed "Part Two: Animal Planet," took place in the backyard of Crider's home. The students entered and found three hens, a pitcher of water, a bowl of sesame seeds, assorted glassware, five cheese pizzas, and one barbeque chicken pizza.
View first occurrence of Fig. 6 in article.
As they entered the backyard, the students tried to discern what they were supposed to do. Most focused on the dinner in front of them. Several noticed immediately a camcorder and tripod pointed at the table and concluded (correctly) that they were being taped again. Some paid particular attention to a television antenna mounted on a short pole. A few noticed the hens and one soon said, "I think we are supposed to do something with the chickens." Six of them eventually threw a few seeds to the hens and stooped briefly to look at them. However, very quickly one said, "I think we're just supposed to eat." Within minutes, all of the pizza was gone. Students spent a few more minutes milling about uncertainly until we instructors finally showed ourselves and we moved into some discussion of the final and then our farewells for the term.

Assessment of the Exam Experiences

In advance of this final we had little idea, frankly, what the students would do. We did, of course, brainstorm possibilities—enough to persuade us that the class in fact had good options for both parts of the final—but we knew, especially for the monolith, that these were only a few of many. In the end, we found ourselves quite happy with the students' actual responses to the monolith, but less happy with their responses to "Animal Planet." We were hoping that the students would have a more meaningful interaction with the chickens, considering them less as the stereotyped dumb animal of the popular imagination and more like other, nearly alien minds. After all, the students were, in a sense, intruders in the chickens' native place—not altogether dissimilar, again, from the KICK Astronauts landing on Aurora. At least they might have tried a more thoughtful and open-ended approach to the animals, and taken more care about the chicken pizza. The COTI experience and the class discussion in its aftermath afforded students some conceptual resources for this approach, and we also tried to prime the pump a bit in advance by instructing the class that the second part of the final was indeed part of the test, and might even have a fairly clear "correct response."
Before the exam, we had a limited rubric in mind for grading this exercise. Eating the chicken pizza *in front of chickens* would be a C; forgoing the chicken pizza but eating the cheese pizza (a very human food) would be a B; while eating sunflowers seeds *with* the chickens, sitting on the ground, would be an A. After watching both video from "The Monolith" and "Animal Planet," however, we found ourselves working out a new, general rubric to evaluate both parts of the final exam.

During the postexam viewing of videotapes, we began categorizing the various behaviors that we witnessed. We initially categorized these merely as A-level, B-level, C-level, etc. until we heard one student on the tape say, *"How would you all have reacted to this on the first day of class?"* This question, coupled with our existing framework, led us to reclassify the activities using new, clearer categories based on the degree of student transformation. Student transformation in higher education often begins with an activating event (Cranton 2002[3]) such as our monolith or the chicken-loud backyard. For Part One: The Monolith, we classified the following statements and behaviors using this rubric:

Level Three
- respond to the instructors' "message" with an similarly enigmatic message
- move the monolith to a meaningful location (with appropriate rationale)
- explore the connection between the nature of the exam and the class
- demonstrate comfort with the ambiguity of the exam
- manifest a "new level of consciousness" (taking the monolith as a "spark") in some other way

Level Two
- research the monolith online
- search for a second monolith
- meditate
- conduct a limited group discussion about the exam

Level One
- complain about the ambiguity of the exam
- email the professors or visit their offices for help

Level Zero
- destroy the monolith
- leave the room without completing the exam

For Part Two: Animal Planet, we classified the following statements and behaviors using this rubric:

Level Three
- sit on the ground with the chickens ("get on their level"—see what develops)
- forgo eating the chicken pizza (unless the chickens eat some first: this could be tried as an experiment)
- eat sunflower seeds *with* the chickens
- offer the chickens water in a chicken-suitable glass vessel while also drinking water from human-suitable glass vessel
- discuss the connection between the nature of the exam and the class

Level Two
- observe the antenna as a possible communication device
- throw chicken seeds to the chickens
- raise and explore questions about the exam

Level One
- see but ignore the chickens
- treat the chickens at pets or livestock

- eat the chicken pizza in the presence of chickens

Level Zero
- hurt the chickens
- chase the chickens

While reflecting on these, we developed a meta-rubric to classify the specific actions in a fashion akin to the VALUE (Valid Assessment of Learning in Undergraduate Education) rubrics created by the American Association of Colleges and Universities (Rhodes 2010[11]). Multiple items in the 14 VALUE rubrics could be used to evaluate our final exam, in particular those related to Creating Thinking, Integrative Learning, Intercultural Knowledge and Competence, and (if we were assigning individual grades) Teamwork. However, based on our own observation, we distilled the transformative effects of the class into the following categories:

Level Three: The student **exhibits a behavior** within the class that is reasonable, appropriate, possibly original, and reflects incorporation of the course material; and **makes a statement** articulating the rationale in those terms.

Level Two: The student **makes a statement** or **raises questions** that is reasonable, appropriate and reflects learning of the course material.

Level One: The student makes a statement or exhibits a behavior that is reasonable and appropriate for the situation **but does not necessarily reflect learning** of the course material.

Level Zero: The student makes a statement or exhibits a behavior that is unreasonable or inappropriate for the situation.

We saw several behaviors for Part One: The Monolith that we identified as Level Three. However, for Part Two: Animal Planet, there was an even mix of Level Two and Level One activities and very few Level Three and Level Zero instances. We saw almost nothing the mirrored the Capstone/Level 4 indicators of the VALUE rubrics (except for those in Teamwork). This might be expected given that these were sophomores. (Still, we speculate that a Level Four transformative effect might be that the **student reveals evidence of impact beyond the classroom** that the course activities and material have had, such as a more reciprocal and less anthropocentric attention to other animals beyond the backyard chickens—but we were not in a position to assess this.)

The Monolith was a completely open-ended final challenge, an invitation to do something creative and appropriate but—"like in the real world," as our students say without a trace of irony—with absolutely no direction about how. We had purposefully left students with merely a few hints from our concluding discussion of *2001:A Space Odyssey*. For example, we noted that in the film the appearance of the monolith signaled and created a "spark" that represented a dramatic change in level of human consciousness. By analogy, then, the unexpected disappearance of everything familiar in our usual classroom and the appearance of our own (rather imposing and indeed "awesome") monolith signaled and invited the class to try to articulate a change of consciousness of their own, somehow. In this case, our students indeed discussed how this class itself represented a shift in consciousness for them.

It was, at the very least, an "awesome" final not just in the sense that the monolith itself was physically awesome (8-feet tall, solid deep black, and quite heavy) but also that it once again put students thoroughly and completely "inside the questions" posed by the class, and this time in a totally open-ended and high-wire way. They had to figure out how what we had done in that room over the term could somehow be imagined to crystallize a change in human consciousness as such, and how such a change could be made manifest to others, at least as far as one small group of young humans might take it in two hours. Experiential education on the edge, indeed. In this sense, we are not saying that this was the best final exam in the history of final

exams. Neither was it the most challenging, the most beautiful, nor the most provocative. However, we think it was *very* awesome.

"Animal Planet", meanwhile, returned to the dynamic of the Astronaut-Auroran alien encounter, as well as picking up of some of the themes of course relating to communication with other animals (or as Weston would put it, Other-Than-Human Minds) right here on Earth. How would the students be with the chickens, after all was said and almost all was done?

Here is part of what we wrote to the students afterwards about this part of the final:

Our basic question was: having finished this class with multiple discussions of alien (and animal) intelligences and gone through the COTI simulation in particular, where the "pet" issue was central, how would your response to the chickens differ from the likely response of students who'd not taken the class? In the event, we saw some evidence, in some of your responses, that you were taking the chickens as other forms of intelligence and as such, co-inhabitants (or natives) of the backyard with perspectives and needs of their own that you could relate to. We also saw a number of responses that suggested that some more learning is needed here….

We did hear someone raise the question "how do we find an answer to this?" Someone else said: "I think we just eat"… hmmm… Again: this is a reprise of the Aurora situation! You need to *do something* with the chickens. (Somebody said that: "We need to interact with the chickens" … but as a group you didn't follow through.) You were partially redeemed because some of you did momentarily start to relate to the chickens, though we're not sure anyone got all the way out of "pet" mode, at least as far as we saw. Perhaps if you'd had more time you would have figured this out and gotten more systematic about it—much as you did with the monolith, which also started out (naturally) confused and somewhat scattered. However, while the time scale of "Planet Monolith" is very slow and forgiving, the time scale of "Planet Chicken" is not. Once the chicken pizza has been consumed, it is hard to "uneat" it. (This itself is a metaphor for other human challenges, of course.) Much like the KICK Astronaut experience, the will and inertia of the crowd overcame the few voices that hinted, "Maybe we shouldn't do this."

It was not a bad point to end the class on, though: with the reminder that the question of relationship remains, and that, in a sense, we can never have enough humility, learned as we might be, as we stand in confusion as well as awe before a world that will, and should, always continue to surprise us.

DISCUSSION

The blend of astronomy and philosophy used in our *Life in the Universe* class is uncommon, if not unique. Likewise, the class activities and exams described above are atypical, even at institution such as Elon University with a strong emphasis on experiential education. Our aim therefore is not to offer a whole-class pedagogical template that other instructors can transfer wholesale to their own classes. We do hope, however, that there might be some other useful lessons in it for a larger audience.

First, some of the specific activities we developed should be transferable to specific themes in astronomy and related classes (even in philosophy). Most notably, the first activity, "Someone is Looking for You," offers a vivid and challenging way to introduce a class to the assumptions behind the contemporary SETI (that is, more or less on the Cocconi and Morrison model), as well as its riskiness and inevitable frustrations and cross-purposes. Again, though the probability of success is unclear but surely much less than 100%, our reflection in retrospect was that failure to make "contact" would have been at least as instructive as success, if not more so.

We recommend, as well, the COTI project, although it requires a much longer time span and much more class time. Again, there is an order of magnitude difference between reflecting on the potential pitfalls of first contact from a distanced classroom perspective, and finding yourself, on the other hand, a beleaguered

explorer on a strange world, desperately trying to save a mission, or contrariwise a denizen of a settled planet suddenly and just as desperately having to deal with incomprehensible invaders from the sky. In this way students began to truly understand the rather disastrous legacy of encounters with other minds and societies, both human and other-than-human, to date. This sort of role-play has been shown to be effective at developing student empathy in other classes (Stroessner, Beckerman, and Whitaker 2009[16]) and was in this class, as well. There is an epistemological lesson here too: that anything alien is likely to be far stranger than we imagine (or, as Haldane famously put it, stranger than we *can* imagine) so that we are very likely to miss it without extraordinary circumspection and care. And maybe even then.

COTI itself has been running such simulations for almost thirty years, so a good deal of experience has been built up with them, and a variety of outcomes have been observed. They have used both the model we borrowed, with one alien species encountered by future human explorers, and a model with two different alien species encountering each other. In recent years the latter model has predominated largely because it proved difficult to generate as much interest in the human group as in inventing aliens (see Note-3). In our own experience, this was not too difficult, though, and our view is that both are equally fascinating, just in different ways. No doubt many of the same points emerge either way.

Our final exam is probably not one that many instructors will rush to replicate. We cannot even replicate it ourselves, actually, because the story of this class has already entered the lore of the Honors program at Elon. Next time, we will have to do something else to catch them unawares. Still, we offer it as at least a possible inspiration for other finals. One of the things we all want for our students is for them to be thoroughly intrigued by and engaged with the class material. Keeping them a little off-balance and challenged in such ways is one means to do so. The concluding moment of a class is also a critical occasion for such an activity. At the very least, there is no need to use the final time – usually much longer than a typical class period—just for a kind of extended regular writing session. Our advice is to do that on one of the last class days and save the final time for something quite different, and special.

More basic to the philosophy of our approach, once again, is the aim to bring students "inside the questions" rather than exploring them solely at arms' length in the traditional distanced academic way. This was our design principle, in fact: that as much as possible we wanted to bring the students into active engagement with the questions, posed with unavoidable urgency and as practical challenges, right in front of them, which had to be met. Recall again the features of experiential education enumerated at the beginning of this paper. You can see them most clearly at work in "Someone is Looking For You," a totally real situation that nonetheless was a close structural analogue to the Cocconi-Morrison framework. Having struggled, under time pressure but with the undeniable intrigue of searching for someone like them who at the same time was searching for them, students got an unparalleled sense of contemporary SETI itself. The same aim motivated our other activities as well, along with still other, more familiar methods we used in this class, such as setting up the students to reenact some of the international political and scientific conferences, faced with key decisions, that Sagan imagines taking place in *Contact*, or setting up a full-scale symposium and team debate between different answers to the Fermi Paradox.

Still more broadly, by way of conclusion, the most philosophical moral of our story is that it is both possible and enormously invigorating to "teach on the edge" (Weston 2003[20]). No doubt it helped a great deal that our topic itself was already on the edge, by comparison to the usual academic topics, so that a greater speculativeness and freshness were to be expected. Still, its very unfamiliarity might just as readily have inclined us and our students to greater pedagogical timidity. We hope that the spirit of these projects might inspire some others to get a little edgier themselves. Much more is possible in university classrooms—science classrooms very much included—that we usually imagine, and even "failures," in well-planned activities, can be as instructive (or more so) as successes. And besides: all of this is vastly more fun!

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Notes

The full list of twelve principles describing experiential education, as defined by the Association for Experiential Education, can be read at http://www.aee.org/about/whatIsEE/.
The students' Aurorapedia can be read in its entirety at http://aurorapedia.wikispaces.com/. The KICK Astronauts: Project Discovery mission plan can be read at http://bit.ly/KICKAstronauts.
During the semester we taught this class, Weston was able to take part in COTI 2012 and was part of a group that invented an alien species called the "Graxes": for an epic-poem version, see http://bit.ly/GraxesRockPoem.

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