

Teaching Portfolio

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Statement of Teaching Philosophy

I teach astronomy out of a desire to share with students what I believe to be important and profound truths:

- 1) That the natural world is knowable, and we are able to know it through science.
- 2) That science is not a guarded secret, but rather a way of thinking available to all.
- 3) That understanding the universe is a way for us to better understand ourselves.

The natural world is knowable, and we are able to know it through science:

One of the most valuable skills I can hope to leave my students with is that of scientific literacy. For some students, my introductory astronomy course may be the only college science class they ever take, possibly their only window into understanding and evaluating the scientific results that surround us daily. For others, I may be their instructor in an upper level physics course, helping steer them through a part of their path toward a research career. In either case, I believe that the most useful role that I can play is not as a dispenser of knowledge, but rather as a resource and guide that they use in the process of discovering answers for themselves. I challenge my students to evaluate not just *what* we know but *how* we know it. I ask them to use critical thinking to propose their own solutions to complex problems. I invite them to teach and mentor their peers as they apply new ways of thinking. And I guide them as they learn how to facilitate their own learning and growth. These skills are vital not just for scientists, but for students of all disciplines. And in a world of rapidly accelerating technology and deeply politicized science results, the ability to make critical judgements for oneself is of crucial importance. As such, science literacy skills of this kind are suggested to be the most important focus for introductory astronomy education (Partridge and Greenstein, 2003).

To accomplish these goals, my courses are founded upon active teaching methods that engage students directly in the scientific thought process. I believe that as a science educator, it is my responsibility to use the teaching methods that are shown scientifically to be most effective and engaging, namely active learning (e.g. Hake et al., 1998; Bailey and Slater, 2003; Freeman et al., 2014). In each of my class periods I incorporate a range of active learning techniques, including guided inquiry exercises, class discussions, clicker questions, and think-pair-share frameworks, all of which are demonstrated to aid student comprehension (e.g. Weaver et al., 2008; Prather et al., 2009, Smith et al., 2009). Class assignments focus on deep conceptual understanding, requiring students to connect and evaluate ideas from several different areas to solve a problem fully. Throughout my courses, group work and collaboration are encouraged and often required, as these cooperative learning styles are shown to enhance student achievement, develop higher-level cognitive strategies, and promote positive peer relationships (Roseth et al., 2008; Johnson and Johnson, 2011; Freeman et al., 2014).

The use of these methods is certainly valuable, but I find that an even more important part of being an educator lies in regularly evaluating the effectiveness of my teaching and making revisions as necessary. As I teach, I establish specific and measurable learning goals, and frequently assess whether students are achieving these goals. This allows me to recognize which aspects of a course need improvement, and to constantly iterate and build upon them. Sometimes this simply involves the rewording of an activity, while other times it requires the complete redesign of a unit using newly learned teaching strategies. I work to stay up to date on these strategies by reviewing the literature, discussing ideas with colleagues, and seeking professional development opportunities. These include a national STEM education workshop I recently attended, administered by UC Santa Cruz's Institute for Science and Engineering Educators, as well as a graduate school course I completed on college-level STEM education. Experiences of this sort, along with large amounts of student feedback, allow me to continually reflect on what is working and what is not. One of the most valuable teaching experiences I've had thus far was the opportunity to teach a college summer course for a second time, using the pedagogy I had learned through classes and workshops to rework and improve large sections of the curriculum.

Science is not a guarded secret, but rather a way of thinking available to all:

Central to my teaching philosophy is the belief that all students have the potential to grow into brilliant scientists. All too often, students fall into a fixed view of intelligence, believing that they are in some way innately unable to progress in math and science. This viewpoint is not only incorrect based on our understanding of how expertise is formed (Bransford et al., 2000; Ross, 2006), but also has been shown to have negative impacts on student achievement, engagement, and self-efficacy (Dweck and Leggett, 1988; Hochanadel and Finamore, 2015).

In my teaching, I work to counteract this by promoting a classroom culture that is built around growth-oriented thinking. I challenge students to find ways to push just past the edge of their abilities, emphasizing that struggle and hardship are natural, positive parts of the learning process (Bjork, 1994). I sit with students as I encourage them to analyze how they are approaching a problem, help them think of other strategies they could try, and ask them to frequently reflect on the progress they have made. Thinking metacognitively in this way has been shown to hold a variety of benefits for students. It enhances their ability to transfer their knowledge to new contexts and conditions (White and Fredericksen, 1998; Halpern et al., 1998). It provides them with a form of scaffolding that they can use when they encounter topics that are entirely new to them (Holton and Clarke, 2006). And it helps facilitate a growth mindset, contributing to their self-efficacy and academic success (Austin et al., 2018).

In building a classroom community that is focused on growth and progress, I find it to be vital that class assessments reflect these values. Students respond to the system of grading that an instructor imposes on them, directing their attention towards the skills that are highlighted as being important. For this reason, I make sure that the feedback that I provide students, whether through written notes, grades, or conversations, is focused on their ability to synthesize and

apply new concepts, their level of deeper comprehension, and the learning that they've achieved. I put a strong emphasis on formative assessments in my teaching, using in-class learning activities, think-pair-share questions, and a variety of Classroom Assessment Techniques outlined by Angelo and Cross (1993) to facilitate regular check-ins. These allow me to determine the extent to which students are achieving my course learning goals, and also give students an opportunity to reflect on their own learning. On the broadest of scales, I believe that the most important role of assessments is that of helping students and myself recognize the areas in which they've improved and the areas in which should apply more time and effort, and I work to ensure that my feedback reflects this.

A necessary component of believing that everyone has the potential to become a scientist is recognizing that in our current society not everyone has the opportunity to do so. STEM careers and research positions severely underrepresent women and racial minorities, an issue that needs to be addressed at all levels of education. In my classroom, I use research-based strategies to create a learning environment that is inclusive and supportive for all students. I employ active learning and peer instruction methods that are shown to increase the retention and performance of students in underrepresented groups (Kinzie et al., 2008, Estrada et al., 2016), and I place a particular emphasis on instilling a positive science identity in all students I teach. This involves designing course materials that are focused on conceptual understanding and real-world relevance, and taking time to provide students with regular recognition of scientific abilities, both of which are shown to contribute greatly to the development of a science identity (Carlone and Johnson, 2007; Hazari et al., 2010).

Understanding the universe is a way for us to better understand ourselves:

Astronomy, more than most fields, is often viewed as detached and removed from human experience, but I don't find this to be true. The vast context of the universe, existential as it might be, is one of the only things that truly connects us all, and I endeavor to give students a glimpse of this through my teaching. I connect our study of space sciences to ideas in philosophy, history, and anthropology, asking students through essays and debates to examine the humanistic questions that underly our study of the cosmos. I see this as valuable not just in making students well-rounded, but also in developing their ability to communicate science ideas effectively. In a landscape where funding is becoming increasingly competitive and the public frequently responds to science with apathy or distrust, the ability to present an engaging and convincing argument for why these things matter might be the most important skill of all.

It is true that teaching classes in this way does ask quite a lot from my students, but I let them know that they can also ask quite a lot from me. They can expect me to challenge them but not overwhelm them, know that I will treat them with fairness and honesty, and trust me to teach them things that I find deeply important, which I do. In teaching astronomy, I see no greater importance than guiding students as they explore the breathtaking context of our world and our lives. In doing so I hope to help them appreciate what that context could mean for how we interact with each other, the world, and ourselves.

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Teaching Experience

Instructor of Record

ASTR 2040 - The Search for Life in the Universe, *Summer 2019*
Undergraduate level, 32 students

ASTR 2040 - The Search for Life in the Universe, *Summer 2017*
Undergraduate level, 27 students

Teaching Assistant

ASTR 101 - Introductory Astronomy, *Spring 2014*
Undergraduate Non-Majors, 110 students

AOSS 380 - Radiative and Dynamic Processes, *Fall 2013*
Undergraduate Majors, 18 students

Extra-Curricular Programs

MASP PEAC summer program for undergraduates, *Summer 2019*
- *Designed and facilitated a day-long inquiry activity for incoming freshmen from traditionally underrepresented groups.*

Astronomy Day at CU Boulder, 2014-2016
- *Designed and facilitated learning activities on the MAVEN mission to Mars and its science goals.*

Private Tutoring

Physics, Math, and C++ Programming, 2010-2014

Target Course - The Search for Life in the Universe

Course Title: Astronomy 2040 - The Search for Life in the Universe

Course Level: This course is designed as an introductory science course for freshman and sophomore undergraduates. It can be taught to both non-majors and majors, as the course material covers a wide range of disciplines, meaning that no student will enter the class as an expert on all subjects.

Pre-Requisites: Students are expected to have taken a high-school level physics course, as well as math courses through pre-calculus.

Size: Target class size is between 20 and 30 students. The course makes extensive use of in-class learning activities and group discussions, and facilitation becomes more difficult once the class size becomes larger than 50.

Learning Goals

Course-level learning goals:

These overarching goals describe what a student will be able to accomplish by the end of this course. They are intended to represent valuable, testable science skills that serve as the backbone for design of the curriculum. Each unit of the course, while having its own specific learning goals, will also contribute to student mastery of the course-level learning goals.

The design of these learning goals was greatly influenced by Partridge and Greenstein (2003), who report on the findings of two national summits of astronomy department leaders. These summits were instituted by the American Astronomical Society with the purpose of establishing strategies for providing meaningful and effective introductory astronomy education. They concluded that content goals for these classes should focus on student development of general science skills, and argued for increased depth over breadth, emphasizing that having students engage with a few concepts comprehensively is more valuable than surveying the entire field of astronomy.

Students will be able to propose observations that could defend or disprove a scientific theory, and provide explanation for why these observations accomplish this.

Students will be able to evaluate a scientific argument with skepticism, and provide an argument for why or why not it is trustworthy.

Students will be able to construct, defend, and analyze order-of-magnitude estimates across a variety of contexts.

Students will be able to use scaling laws to determine the relative importance of different physical quantities.

Students will be able to analyze uncertainties for a scientific measurements, using them to determine whether or not provided results support a science theory.

Students will be able to interpret the potential habitability of a planetary body using observations and data.

Students will be able to use scientific evidence to construct an argument for whether or not life is likely to exist outside of Earth.

Unit-level learning goals - Icy Moons:

Unit-level learning goals describe what a student will be able to accomplish after completing a particular unit of study. Below I've listed the learning goals for a one-week unit titled "Icy Moons". These are representative of how I approach drafting learning goals for other units in courses I teach. In this course, other units include "Searching for Exoplanets", "History of Life on Earth", and "Mars, Past and Present".

Students will be able to compare the features of different icy moons in the outer solar system and develop arguments for which might be the most likely to be habitable

Students will be able to explain how tidal heating creates subsurface oceans on icy moons.

Students will be able to explain *how* we know that icy moons contain subsurface oceans.

Students will be able to propose and evaluate potential observations that could help determine the habitability of an icy moon.

References

Partridge, B., & Greenstein, G. (2003). Goals for "ASTRO 101": Report on workshops for department leaders. *Astronomy Education Review*, 2(2).

Lecture Tutorial - Exoplanet Transits

Background

Lecture tutorials are learning activities that students work on in groups during a class period, either before or after a lecture. They are intended to introduce or expand upon challenging ideas discussed in the lecture, with a series of increasingly difficult questions designed to guide students toward deeper understanding.

Examples of different types of lecture tutorials can be found in *Hanson et al.* (2006), *Prather et al.* (2009), *Slater et al.* (2010), and *Kortz and Smay* (2010). These authors show that by presenting the material in a more engaging way and encouraging students to explain ideas to each other, these learning activities help students address their own level of understanding, correct misconceptions, perform better on exams, and are suggested to help students develop a more scientific method of thinking.

Implementation

This lecture tutorial is designed to introduce students to the transit method of exoplanet discovery. It should be given at the start of a class period, and will be followed by a short lecture that summarizes the ideas presented in the worksheet and then expands upon the topic. In completing this worksheet, students will come up with the formula for transit depth on their own, and then use this to analyze actual data.

Steps for implementation:

- 1) At the start of the class period, give each student a copy of the worksheet, and explain to them that today we they will be learning about how we discover planets outside our solar system.
- 2) Have the students **pair up** and begin the worksheet
- 3) As the students work, walk around the room to check in on students, answer any questions they may have, and provide hints and probing questions if they are stuck.
- 4) The Lecture Tutorial should take ~30 minutes to complete. At around this time, regain class attention to start a discussion.
- 5) Go over the questions on the worksheet, asking students to volunteer and explain answers to the class. For the last few questions, make sure to ask for multiple different answers and viewpoints, and have the students discuss.
- 6) Collect worksheets and begin the short lecture.

References

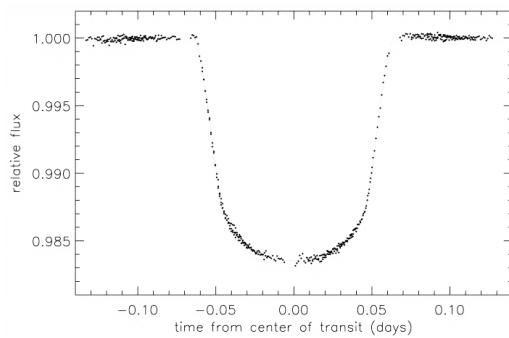
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Exoplanet Transits

One of the ways that we search for exoplanets is by looking for times when these planets pass in front of their host star, dimming its light. We call this the **transit method**.

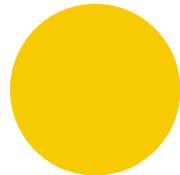
In this activity we're going to explore the transit method, and by the end we'll be using the data below to calculate the actual size of an exoplanet! But don't worry about that yet.

Exoplanet Transit Data:

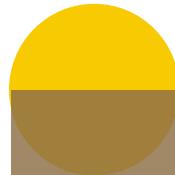


When a planet passes in front of a star, it blocks part of the star's light, meaning that we see less light here at Earth. Below are examples of stars with some fraction of their light blocked by strange shapes.

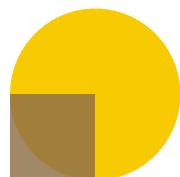
- 1.) For each example, label the fraction of the star's light that is blocked.



Fraction of light blocked: 0



Fraction of light blocked: 1/2

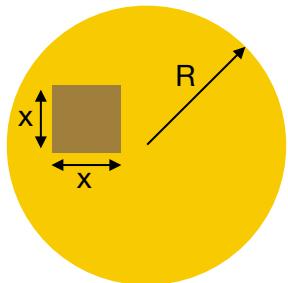


Fraction of light blocked: 1/4

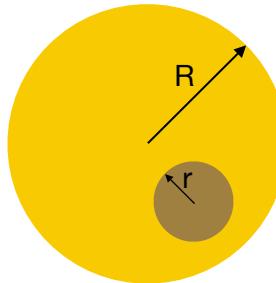


Fraction of light blocked: 1/8

Sometimes we can't get an exact number, and instead make a formula. Try these:



Fraction of light blocked: $\frac{x^2}{\pi R^2}$



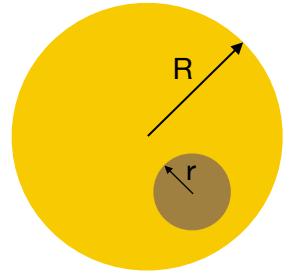
Fraction of light blocked: $\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2$

The last example on the previous page is a good representation of a planet moving in front of a star.

Let's say the star has radius $R = 700,000$ km (the radius of our sun).

2.) Using your previous answer, what fraction of light would be blocked by a planet of radius $r = 70,000$ km? (roughly the radius of Jupiter)

$$\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2 \quad (70,000 / 700,000)^2 = 1/100 = 1\% \text{ of the light}$$



3.) How much light would be blocked by a planet of radius $r = 25,000$ km? (roughly the radius of Uranus)

$$\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2 \quad (25,000 / 700,000)^2 = (1/28)^2 = .0013 = 0.1\% \text{ of the light}$$

4.) How much light would be blocked by a planet of radius $r = 7,000$ km? (roughly the radius of Earth)

$$\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2 \quad (7,000 / 700,000)^2 = (1/100)^2 = .0001 = 0.01\% \text{ of the light}$$

Now let's try working in the other direction.

If we know how much light is blocked, we can figure out the size of the planet.

Using the same star of radius $R = 700,000$ km...

5 a.) If 5% of the star's light is blocked by a planet, what is the radius of that planet?

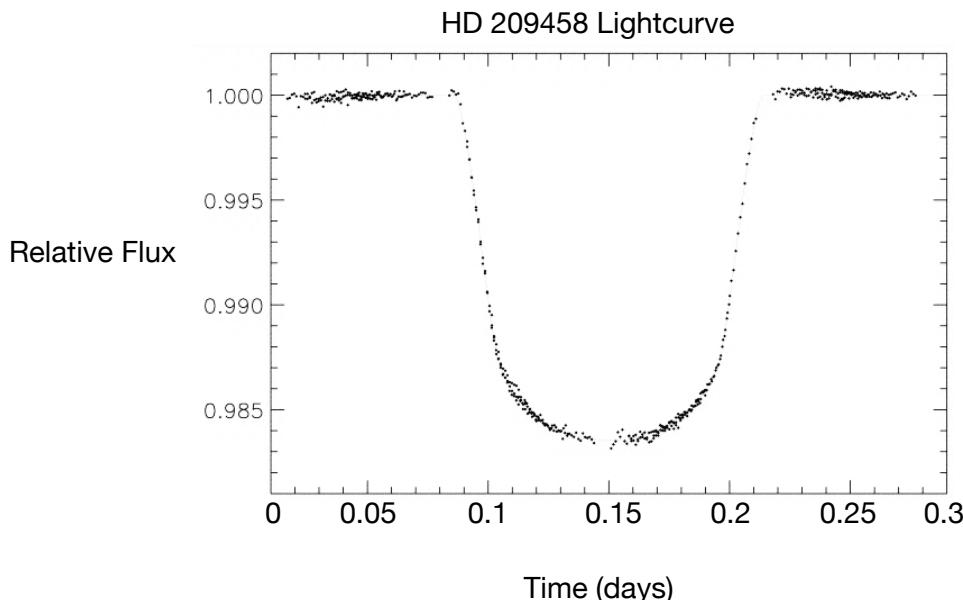
$$\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2 \quad (r / 700,000)^2 = .05 \quad (r / 700,000) = 0.224 \quad r = 156,500 \text{ km}$$

b.) Would this be a big planet? Compare it to the sizes of Earth and Jupiter.

This would be a massive planet, over twice the radius of Jupiter!

Now let's use some data!

Below is a plot of a "lightcurve" for the star HD 209458. This tells us the amount of light that we are receiving from the star over time.



The **x-axis** of this plot shows us **time** elapsed.

The **y-axis** shows us the **amount of light** we are receiving from the star. It is in units of "relative flux", where a value of 1.00 means that we are receiving 100% of the usual light from the star.

In the center of the plot we can see a period of time when the light from the star decreases, meaning it is being blocked by a planet!

We know that HD 209458 has a radius of 84,000 km (1.2 times larger than our sun)

6.) Using the information on the previous page, calculate the radius of the planet that is blocking the light from HD 209458. Explain your work as you go.

The light dips down to ~.985 relative flux, which means 1.5% of the star's light is being blocked by the planet. We know that the star's radius is 84,000 km, so we can now solve for the size of the planet.

$$\frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2 = .015 \quad \left(r/84,000\right)^2 = .015 \quad r/84,000 = 0.122 \quad r = 10,250 \text{ km}$$

Some questions that may be helpful to answer along the way:

- What fraction of the star's usual light are we receiving?

- What fraction of the light is blocked?

7.) Is this a big planet? How does it compare to the sizes of Earth and Jupiter? Do you have a guess as to what kind of planet this might be?

Answers may vary: This planet is slightly larger than Earth, but still much smaller than either Uranus or Jupiter. Based on this, I'm guessing this is probably a rocky planet of some kind, but perhaps it could be a very small gas giant?

8.) Do you think this method of finding exoplanets would be better at finding large planets or small planets? Why?

Answers may vary: Since we're looking for a decrease in the amount of light we receive from the star, it probably will be easiest to notice planets when that decrease is large. This would happen when a large planet moves in front of the star, so I'd think that this method would be best at finding large exoplanets.

GRASPS Formative Assessment - Making a Moon Mission

Background

GRASPS is a framework for designing student performance tasks that was introduced by Wiggins and McTighe (2005). These performance tasks are intended to mirror real-life challenges, providing students with a simulated setting and problem and asking them to produce a solution to that problem meeting specific constraints. By mirroring authentic situations in this way, these assessments help students practice applying their core knowledge and skills to new situations, helping them identify more clearly as a scientist as they do (Bloom et al., 1981; Wiggins and McTighe, 2005).

As an example of formative assessment, GRASPS activities are designed as tools to be used and iterated on during the learning process. By revealing student understandings and misunderstandings, formative assessments provide valuable feedback that both guides future teaching and aids student comprehension (Handelsman et al., 2007). This type of assessment encourages students to assess and monitor their own learning, promoting metacognitive strategies that have been shown to enhance student achievement (e.g. Bransford, 2000).

Implementation

This GRASPS activity is designed to give students experience proposing and evaluating scientific measurements with respect to their possible scientific implications. It is framed around making comparisons between different potentially habitable moons in the outer solar system, and is intended to be used near the end of a unit on icy moons.

Implementation Steps:

- 1) This can be given either as an in-class activity at the end of a class period, or as a short take-home assignment. In either case, one should begin by describing to students the goals of the assignment and how long you would like their responses to be (likely one page or so).
- 2) Have students work on the task individually, and once students are finished (or at the beginning of the next day) collect their executive summaries.
- 3) Give each completed assignment back to a different student for peer review
- 4) Ask the students to write down their name at the top of the page, as well as the name of whose assignment they are reviewing.

- 5) Ask them to read through the executive summary, and to write down a list of at least a few strengths and potential areas of improvement. Then ask them to respond to the prompts that are contained in the rubric (*evaluation of measurements, evaluation of choice of moon*).
- 6) Collect the summaries again, and then repeat steps 3-5 (so each student reviews two summaries).
- 7) Collect everything and move on to the next part of the class.

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- Wiggins, G., & McTighe, J. (2005). *Understanding by design*.

Making a Moon Mission

This activity is designed to give students experience proposing and evaluating scientific measurements with respect to their possible scientific implications.

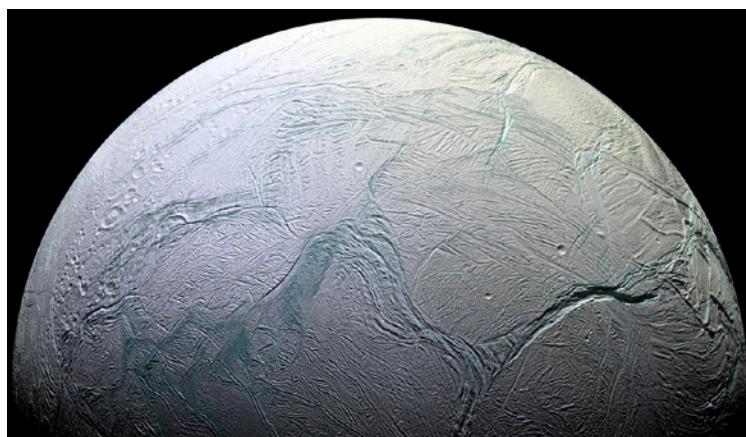
In recent years, NASA has listed the outer moons of our solar system as one of the most likely places that life could exist outside of Earth, and has made the exploration of these moons a priority. With this in mind, take the role of a research scientist working here at University of Colorado, specializing in astrobiology. You've been tasked with proposing a NASA science mission to be sent to a moon in our outer solar system. The primary goal of this mission is to study the potential habitability of this moon, and to search for any evidence of life, if possible.

During the first steps of this proposal process, you need to create an "Executive Summary" document that outlines the main features of your proposed mission. This will act as an overview that you can provide to the panel of NASA scientists and engineers who are deciding which mission to fund.

Your Executive Summary should be a minimum one page document that includes several key elements:

- (1)** Which moon you've chosen as the target of study. (3 pts)
- (2)** An explanation for why that moon is of particular scientific interest, specifically in comparison to other moons you could have chosen. (10 pts)
- (3)** An overview of what type of spacecraft you will send to this moon, and why. (10 pts) (e.g. Will you send a rover? An orbiting satellite? Something else?)
- (4)** A description of 2-3 key measurements or observations you will take, with an explanation of how these measurements contribute to the goal of the mission. (10 pts)

As an expert in this field, you will also be asked to read several of your peers' Executive Summaries and provide feedback. (10 pts - during next class period)



Making a Moon Mission — Rubric

The executive summary needs to include:

Which moon you've chosen as the target of study. (2 pts)

Student states which moon they are studying (2 pts)

An explanation for why that moon is of particular scientific interest, specifically in comparison to other moons you could have chosen. (10 pts)

- *Student provides reasons for why this moon is of particular interest (3 pts)*
- *Reasons provided are accurate and relevant (3 pts)*
- *Student makes comparison to other moons they could have chosen (2 pts)*
- *Comparison states why the chosen moon is of more interest. (2 pts)*

An overview of what type of spacecraft you will send to this moon, and why. (10 pts) (e.g. Will you send a rover? An orbiting satellite? Something else?)

- *Student states what kind of spacecraft they will send to the moon (2 pts)*
- *Student provides reasoning for why they chose that type of spacecraft (4 pts)*
- *Reasons provided are accurate and relevant (4 pts)*

A description of 2-3 key measurements or observations you will take, with an explanation of how these measurements contribute to the mission goal. (10 pts)

- *Student describes at least 2 measurements that will be taken (2 pts)*
- *For at least two of these measurements, student provides reasons for how they contribute to analyzing the habitability of the chosen moon. (4 pts)*
- *Reasons provided are accurate and relevant (4 pts)*

During the next class period, students will each read two of their peer's Executive Summaries (with a prompt).

For each peer review (5 pts):

- *Student evaluates whether the proposed observations contribute to the goal of the mission, explaining why they agree or disagree (3 pts)*
- *Student evaluates the argument for why the moon is of particular interest, with an explanation for why they agree or disagree. (2 pts)*

Contrasting Cases Group Activity - Radiometric Dating

Background

Contrasting Cases activities are quick learning tools that use collections of related but contrasting examples to engage students in understanding a topic on a deeper conceptual level. By examining the similarities and differences of the different elements, students are able to discover underlying concepts and form mental frameworks for the knowledge (Bransford, 2000; Schwartz et al., 2011). This allows them to transfer this knowledge to new contexts and problems much more effectively.

This type of in-class active learning activity is typically completed in groups, asking students to work together, discuss possible solutions, and explain concepts to one another. Well-facilitated group work of this sort asks students to engage in peer instruction, which has been shown to help students assess their own learning, better understand the material, and develop positive peer relationships (Roseth et al., 2008; Smith et al., 2009; Johnson and Johnson, 2011).

Implementation

This Contrasting Cases activity is designed to introduce students to the way in which scientists use radiometric dating to determine the age of samples. It should be given at the start of a class period, following a very brief lecture on radioactive decay. In completing this activity, students will form a concept of half-lives, and will use this concept to determine how isotope concentrations change at different rates over time. For students that have encountered half-lives in a previous course, this may be a very quick activity, while for others it could take 10 minutes or so.

- 1) Provide a copy of the worksheet to each student, and have them form groups.
Explain that this activity is on how we use radioactive decay to determine the age of samples.
- 2) As they work on the activity, walk around the room to check in on students and answer any questions they may have
- 3) Students will possibly (or likely) need guidance along the way. Asking them to explain their reasoning for how they ranked the ages of the rocks, and seeing how that reasoning applies to the red rocks might help them approach a final answer.
- 4) Once students have complete the exercise, regain class attention for a group discussion. Go over the questions, asking students to volunteer answers and explanations.
- 5) Collect the worksheets and move on to the next section of the class period.

Answers

The samples, listed from oldest to youngest: **3,1,2**
Sample X should have 4 white dots and 12 black dots

References

- Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn* (Vol. 11). Washington, DC: National academy press
- Johnson, D. W., & Johnson, R. T. (2011). Intellectual legacy: Cooperation and competition. In *Conflict, interdependence, and justice* (pp. 41-63). Springer, New York, NY.
- Roseth, C. J., Johnson, D. W., & Johnson, R. T. (2008). Promoting early adolescents' achievement and peer relationships: The effects of cooperative, competitive, and individualistic goal structures. *Psychological bulletin*, 134(2), 223.
- Schwartz, D. L., Chase, C. C., Oppezzo, M. A., & Chin, D. B. (2011). Practicing versus inventing with contrasting cases: The effects of telling first on learning and transfer. *Journal of Educational Psychology*, 103(4), 759.
- Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, 323(5910), 122-124.

Radiometric Dating

Often in geology, planetary science, or astrobiology, we are interested in knowing the age of some object, but unfortunately the samples we collect don't come with any tag or expiration date.

To determine ages we instead use "radiometric dating", looking at elements that decay over time into other elements. By looking at a snapshot of those elements in a sample, we can determine how long that sample has existed.

On the next page are shown three different samples that we've collected, and in each sample there are two different rocks that are exhibiting radiometric decay, represented by the dots.

Blue dots decay into red dots over time



White dots decay into black dots over time



But these decays **don't** happen at the same rate.

In each individual sample, all of the rocks are the same age

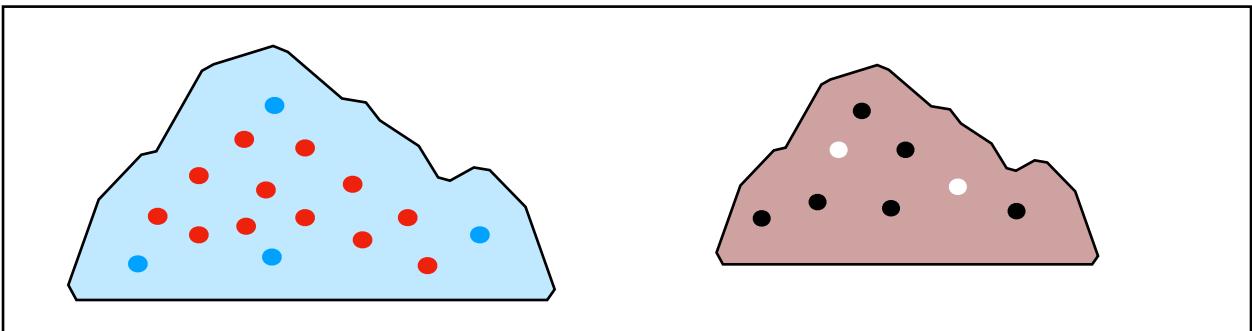
(1) By comparing samples 1 through 3, rank them from oldest to youngest

(2) Next, we've collected one final sample, "Sample X".

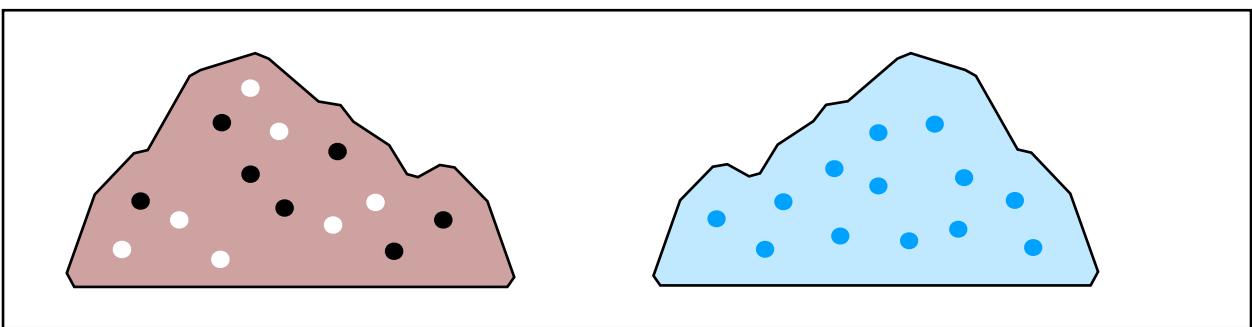
We were only able to fully analyze the blue rock in this sample, but we know that the red rock contains 16 dots.

How many of these dots should be black and how many should be white?

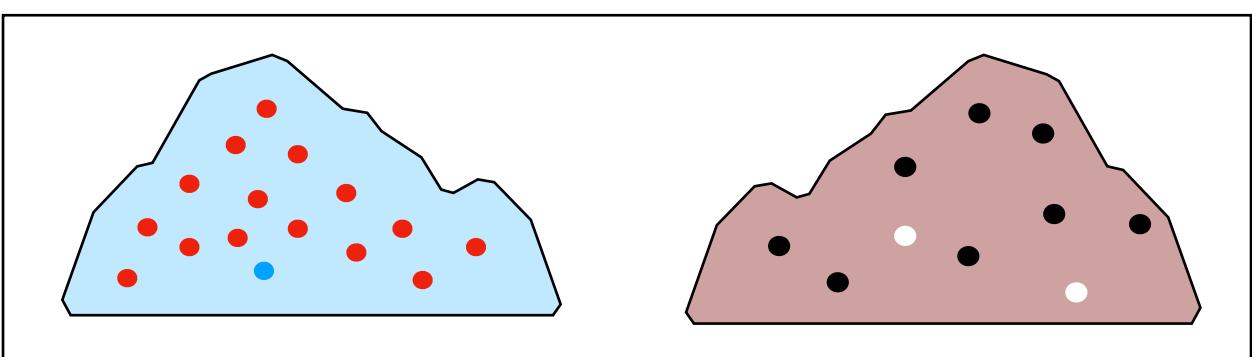
Sample
1



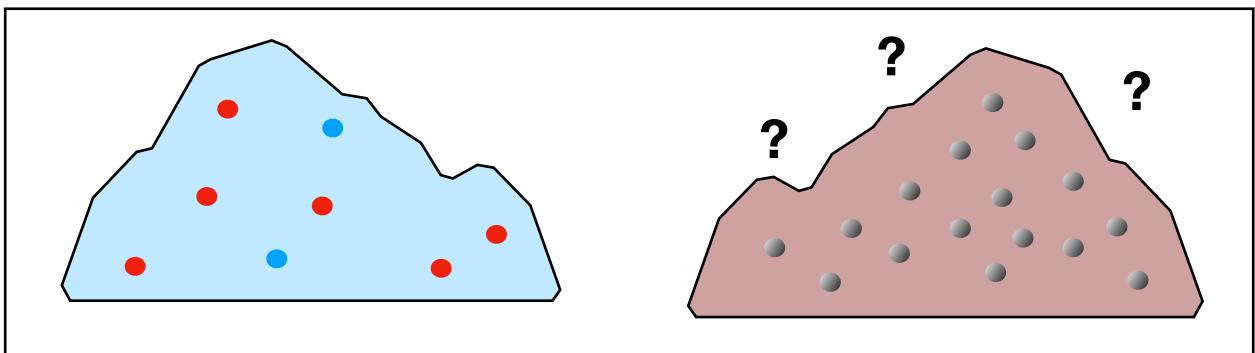
Sample
2



Sample
3



Sample
X



Example Lecture Slides and In-Class Activity - Life on Titan

Background

The lecture slides I show here are modeled after a design that was presented in Alley and Neeley (2005). The authors of this paper point out many flaws with traditional slide designs, which have a tendency to fragment subject matter, obscure the connections between ideas, and produce boring and generic story arcs. The revised design that they propose focuses on two main features: (1) the use of a sentence headline that states the main point of the slide, and (2) the use of extensive visual evidence. These features, along with a decreased amount of text in general, allow students to quickly assess the most important pieces of information and connect them to other ideas in the lecture. Here we additionally make use of the suggestions of Partridge and Greenstein (2003), who point out as part of their analysis of introductory astronomy education that astronomy, more than most fields, is rife with compelling images, and that we should use these images to engage students and give them practice making scientific judgements based on their own observations.

This lecture also ends with a Classroom Assessment Technique (CAT), in which the students are asked to reflect on the information they just learned and apply it to some deeper conceptual questions. CATs come in many different styles, but in general they are quick formative assessments that give both teachers and students feedback on the learning process as it is happening. A variety of different CATs, along with more information on their use, can be found in Angelo and Cross (1993).

Implementation

This mini-lecture is designed to give students a broad overview of Saturn's moon Titan, including the moon's main features, our scientific observations of the moon, and its potential habitability.

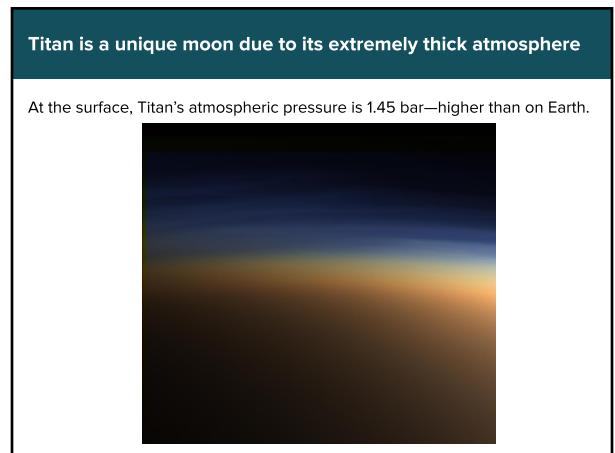
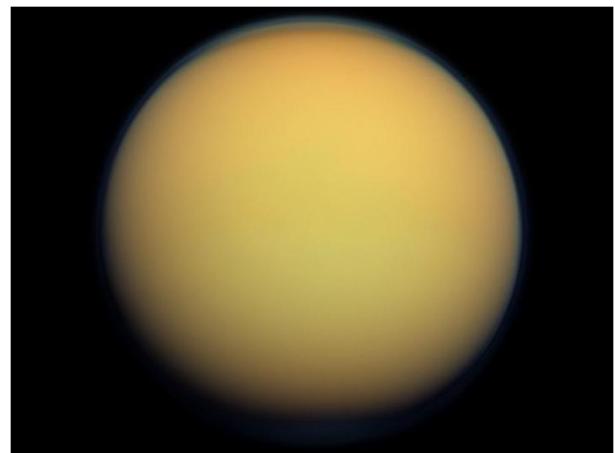
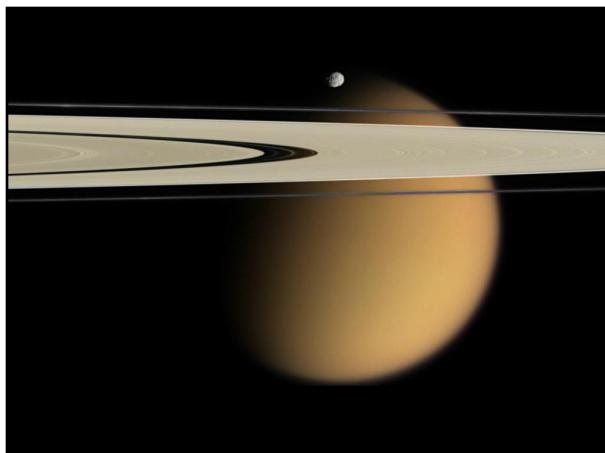
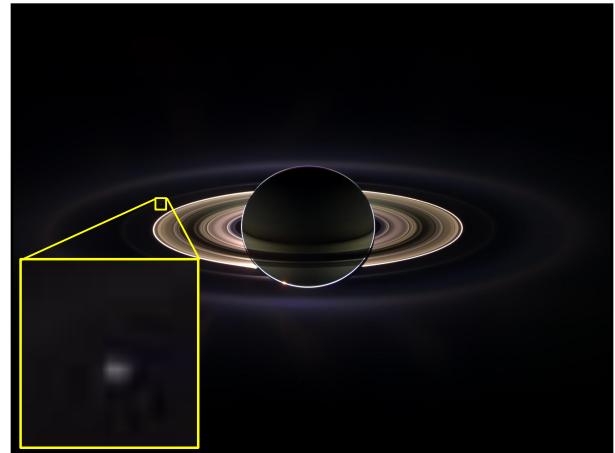
Steps:

- 1) Begin by showing the context slides that show the moon as it relates to Saturn, pointing out any features of particular interest.
- 2) On slide 4, pause and ask the class to describe what they notice about the moon, particularly in relation to its potential habitability. Students will hopefully determine that what we are seeing is a thick atmosphere around the planet, and could make statements about what the color of the atmosphere might imply.
- 3) On slide 8, once again ask students to point out features of interest that they notice. Students should determine that we are seeing lakes and rivers of some sort.

- 4) Continue through to slide 16, describing the different features of Titan and noting how they compare to those on Earth.
- 5) On slide 16, stop and perform the CAT activity using a think-pair-share framework.
 - Ask students to spend 2-3 minutes answering the questions on their own.
 - Then have them pair up and discuss their answers for 2-3 more minutes.
 - Finally, ask for groups to volunteer with their answers to the question, making sure to highlight answers from different groups and facilitate a class discussion.
- 6) Once you've covered a good amount of different possible answers, wrap-up by moving to slide 17, which contains an overview of the types of answers that could have been supplied during the activity.

References

- Alley, M., & Neeley, K. A. (2005). Rethinking the design of presentation slides: A case for sentence headlines and visual evidence. *Technical communication*, 52(4), 417-426.
- Angelo, T. A., & Cross, K. P (2012). *Classroom assessment techniques*. Jossey Bass Wiley.
- Partridge, B., & Greenstein, G. (2003). Goals for “ASTRO 101”: Report on workshops for department leaders. *Astronomy Education Review*, 2(2).



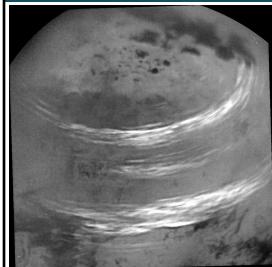
NASA sent the Huygens probe to land on Titan's surface



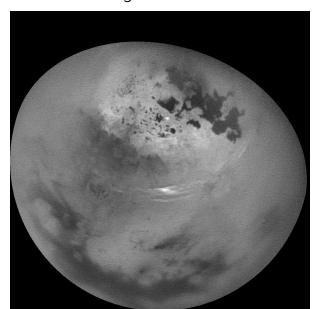
This was the only landing we've accomplished in the outer solar system



Titan's atmosphere is made of nitrogen and methane (CH_4)



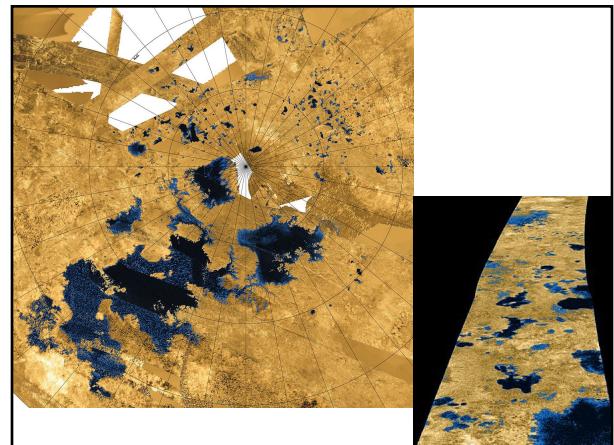
Small clouds of methane can be seen swirling across the surface

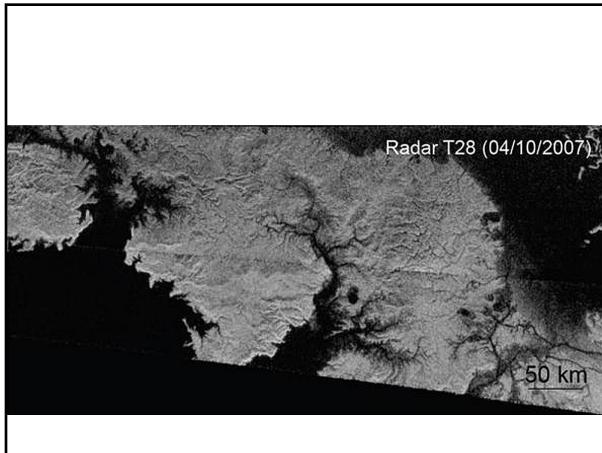


Titan is COLD

At the landing site, the surface temperature was measured at -179°C .

The surface is scattered with rocks and chunks of frozen water ice.



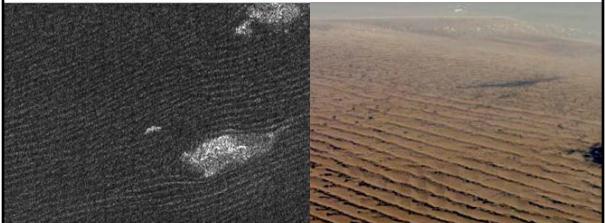


Titan has large dune formations covering much of its surface

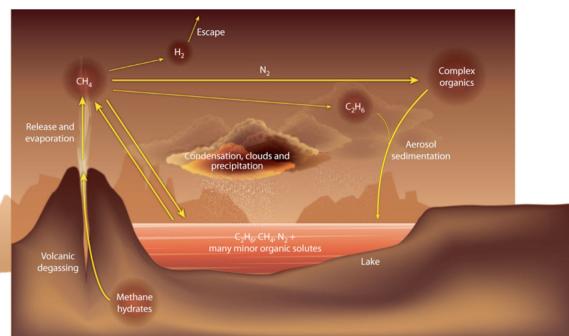
These look very similar to some found on Earth, but must have very different composition...

Titan

Namib Desert



These features suggest that Titan has a methane cycle.



A Habitable Surface?

Titan uniquely exhibits similar meteorology to Earth

Some speculate that this could make for a habitable environment.

Questions:

- 1) Does Titan exhibit all the necessary requirements for life?
- 2) If life were to exist on Titan, in what ways would it differ from life on Earth?

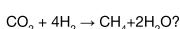
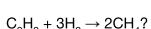


(not a real picture)

Life forms on Titan would be very different from those on Earth

Life on Titan...

Would need to respire **anaerobically**.



Would need to use liquid methane in place of water.

Would need to operate in extremely cold conditions.

Could exist in the subsurface?



Course Syllabus - The Search for Life in the Universe

On the following pages I include an example syllabus for this target course.

This is representative of how I approach writing a syllabus for courses that I teach.

ASTR/GEOL 2040: The Search for Life in the Universe

In *The Search for Life in the Universe*, we will be exploring some of humanity's most persistent questions:

Does life exist on other planets?

How could we find out?

Why is there life on Earth?

How did life on Earth begin?

What makes something "alive"?

What might alien life look like?

In discussing these questions, we'll be exploring many different fields of science — astronomy, biology, geology, physics, mathematics, and philosophy, to name a few. The goal of this course is not for you to become an expert on any one of these topics, but rather for you to engage with a science topics and results in the same way that professional scientists do.

To that end, this course will give you experience with many different aspects of science, including focused inquiry, class discussions and debates, checking results with estimates, explaining results to your peers, and self-guided research. **This is not a course on memorizing facts or formulas, it's a course on thinking scientifically.**

Here are a few of the things that you'll be able to do by the end of the semester:

- Interpret the potential habitability of a planet using observations and data.
- Propose observations that could defend or disprove a scientific theory, and explain why these observations accomplish this.
- Evaluate a scientific argument with skepticism, and make an argument for whether or not it is trustworthy.
- Make and analyze scientific estimates across a variety of contexts.
- Use scaling laws to evaluate the relative importance of different physical quantities

Instructor information

Instructor: Tristan Weber
Office: Duane D130
Office hours: Tuesday, Wednesday, Thursday, 1:00-2:00 PM (or by appt.)
Email: tristan.weber@colorado.edu

Course information

Class time: Monday to Friday, 3:00 - 4:45
Class location: Duane G131
Textbooks: No required textbook, but these two books might be useful:
An Introduction to Astrobiology, David A. Rothery, Ed
Life in the Universe, Jeffrey Bennett

Course Approach and Expectations

This course is taught using collaborative, active learning techniques. **I'm not just going to be talking at you the whole time (yay!).** Teaching in this way is shown to make learning more effective, more long-lasting, and way more interesting. This also means that a major portion of your work and involvement in the course are going to happen in the classroom each day, and the grading of the course will reflect this.

Points breakdown

In-Class Activities:	100 points
In-Class Participation:	50 points
Homework:	100 points (4 x 25)
Midterm exam:	50 points
Final Project:	50 points
Total:	350 points

In-Class Activities/Participation

A large portion of your grade in this course will be based around class activities and discussions. **This does not mean you have to know all the answers during class!** Usually there won't just be one right answer anyway. Rather, these grades can be earned through showing up, putting in effort, and engaging with your classmates and the material. In-Class activities will be graded 80% on completion and 20% on accuracy. In-Class participation will be graded 50% on i-Clicker response completion and 50% on contribution to class discussion

Homework

Homeworks will be posted on our class Canvas site each week. Assignments can be submitted online or in person each Friday. Late assignments will receive a 50% penalty.

Short-answer responses must be in complete sentences. No question can be answered in a single sentence, but if you're using more than a paragraph or two, think about being more concise.

Math problem answers should show all work and contain explanatory sentences. Use words to describe your thought process, list your assumptions, and justify your answer. For the questions in this class, the thought process is much more important than the exact answer, and partial credit will be given readily for If you choose to handwrite your math problems, legibility is key. It might often best to work out the answer and then write up a clean copy.

Working together on homework is encouraged. Science is a collaborative process, and you are encouraged to work together on problems with your classmates. However, all written work must be in your own words and written (or typed) by your own hand. See the CU Honor Code (below) for information on repercussions for academic misconduct.

Final Grades

The final grades for the course will use a fairly standard scale, based on the points breakdown described above.

90-100% — A-, A, A+

80-90% — B-, B, B+

70-80% — C-, C, C+

60-70% — D-, D, D+

<60% — F

Schedule

Note: This schedule is possibly subject to change. Any upcoming changes will be communicated through an email and a post on the class Canvas site at least 24 hours prior to those changes.

Week 1: How We Got to Here

- 11 July – Habitability and the Definition of Life
- 12 July – Life on Earth - What is it, where is it.
- 13 July – Life on Earth - What made Earth habitable?
- 14 July – Life on Earth - Are we special? - Homework 1 Due

Week 2: Looking Outwards

- 17 July – The Earth's place in our Solar System
- 18 July – Mars - A habitable world?
- 19 July – Mars - Searching for signs of life
- 20 July – Venus
- 21 July – Icy Moons - Homework 2 Due

Week 3: Exploring the Solar System

- 24 July – Titan and comets
- 25 July – Exploration of our Solar System and Planetary Protection
- 26 July – Special Topics
- 27 July – Midterm exam
- 28 July – Biosignatures - Homework 3 Due

Week 4: Outside Our Reach

- 31 July – Exoplanets - How to find them
- 1 Aug – Exoplanets - What we've found
- 2 Aug – Exoplanets - What we're looking for
- 3 Aug – The Drake Equation and Fermi's Paradox
- 4 Aug – The Philosophy of Searching for life - Homework 4 Due

Week 5: The Future

- 7 Aug – Life as we don't know it
- 8 Aug – What comes next? - Interstellar travel and the future of us.
- 9 Aug – Special Topics and Review
- 10 Aug – Final Exam
- 11 Aug – No class

Classroom policies

Absences

Regular attendance to class is vital to success in this course. Many in-class activities depend on collaboration with your classmates, and all material covered during class periods could show up on the exam. That being said, if you are sick, please do not come to class! Notify me, and we can go over the material during office hours. If an emergency requires you to miss an exam or the submission of an assignment, please do your best to notify me **before class**. Accommodation of these absences will be handled on a case-by-case basis.

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, homework assignments should be submitted prior to the due date and exams should be completed as near to their scheduled date as possible. See full details at http://www.colorado.edu/policies/fac_relig.html

Discrimination and harassment

Discrimination and harassment of your colleagues has no place in science and will not be tolerated in this course. If the words or actions of myself or any of your classmates are bothering you, please do inform me or the Office of Discrimination and Harassment, such that the issues can be addressed.

The official CU policy is included below:

The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at <http://hr.colorado.edu/dh/>

Classroom behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the CU policies on [classroom behavior](#) and the [Student Code of Conduct](#).

Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.

Accommodations

Even if you do not have an official accommodation, please let me know what would make your learning experience better and I will do my best to address it.

The official CU policy is included below:

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see [Temporary Medical Conditions](#) under the Students tab on the Disability Services website.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional

information regarding the Honor Code academic integrity policy can be found at the [Honor Code Office website](#).

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, we will provide alter