Science on the Fringes

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Introduction

This curriculum is for a semester-long high school elective science course which focuses on “cutting edge” or “fringe” topics and debates within current scientific research. Over the course of the semester, students will explore multiple phenomena, spanning various scientific disciplines, for which current scientific explanations seem to fall short or to hit a wall, and each of which may represent a “paradigm shift” (Kuhn, 1970) in the making or yet to come. Our intent in exploring these topics is not only to develop student understanding of major scientific concepts and how science as a human enterprise is done, but, more importantly, as an invitation for students to see science – scientific knowledge, scientific questions, science as a human activity, and the science classroom – as a terrain in which seeking pleasure and seeking to satisfy the soul or spirit (the inner, more-than-rational, self) are legitimate and worthy aims, and in which imagination, play, and aesthetic ways of knowing can contribute in valuable ways.

1This poem reflects what Catanzano calls “quantum poetics,” the intersections of poetry and physics; we include it here as a model for the kind of aesthetic engagement with science this curriculum invites. (More information about the poem can be found at https://thenextweb.com/distract/2018/10/12/artist-explains-quantum-physics-through-poetry/ or https://physics.aps.org/articles/v11/103. More examples of Catanzano's quantum poetics are at http://poemsandpoetics.blogspot.com/2011/01/amy-catanzano-four-poems-toward-quantum.html.)
Rationale

Philosophy

This curriculum is founded on the premise that education should be for the whole person, not just the person as a future economic producer or consumer, or even just the person as political citizen. More specifically, our curriculum embraces “wide-awakenesses” (Greene, 1978) and pleasure (McWilliams, 1996) as central aims of education that recognize and honor students as both spiritual and embodied beings, rather than posit them as disembodied and calculating minds in the way that traditional K-12 education, particularly science education, too often does. We believe not only that education in general should serve the human in body, mind, and spirit, but also that science education specifically has a crucial role to play in such an endeavor.

Too often, science has been portrayed as primarily, even exclusively, a tool for objective-knowledge and functional-solution creation. We are told that we learn and do science to explain the natural world and to engineer solutions for practical human problems. So, for example, while the Framework for K-12 Science Education (NRC, 2012) pays lip service to the “intrinsic beauty of science (p. 7),” it makes clear that, in the view of its authors, the most important reason for learning science today is to gain the knowledge needed to address global challenges (p. 1, p. 7). Furthermore, it frames the knowledge necessary to tackle these problems as primarily technical in nature, ignoring the sociopolitical forces at play (Weinstein, 2017). Consequently, the standards developed from this framework represent scientific understanding as synonymous with explaining and applying science, neglecting other facets of understanding, such as the understanding shown in interpreting the subjective meaning of a concept, imagining a radically different experience, or seeing oneself differently in light of knowledge gained (Wiggins & McTighe, 2005, p. 82-104). Even some curricular theorists who champion education for
consciousness-raising and aesthetic and embodied ways of knowing and demonstrating knowledge have overlooked the implication of these projects for science education specifically. For example, Greene (1978) explicitly ties the development of “wide-awakeness” to engagement with works of art, claiming “heightened consciousness and reflectiveness are meaningful only with respect to human projects (p. 163),” which seems to deny the potential for nature itself to arouse one’s sense of oneself as free and fully-alive individual.

As an alternative to these perspectives on science and science education, this curriculum recognizes that while addressing current global challenges is one valid reason for learning science, it is by no means the only one. Further, we share Sonu and Snaza’s (2015) conviction that attempts to address these challenges through science will be seriously limited if they are not accompanied by a re-imaging of the physical world – its vitality, agency, and fragility – and our relationship to it, and that, as Carr and Haldane (2003) put it, “a culture that neglects the life of the spirit is one that has not long to live (p. 6).” Thus, the primary aim of this curriculum is for students to experience questions and knowledge related to the “natural” or material world as domains which can serve, and be served by, all aspects of themselves as humans and individuals. This means, on one hand, legitimizing the desire to contemplate the physical world and to seek out and make use of scientific knowledge about the physical world as an exercise in consciousness-raising, for greater wide-awakening, and even “for the fun of it.” On the other hand, it also means challenging limiting notions about what counts as knowledge about the physical world and about how such knowledge may be gained. Students will come to recognize science as a way of knowing, with its own history, its own strengths and powers, but also its own assumptions and corresponding limitations. They will likewise recognize that there is room for debate, ambiguity, and not-knowing when it comes to many of the fundamental questions in the
philosophy of science, answers to which often serve as unexamined assumptions in how science knowledge is pursued and communicated. These include questions about the nature of reality, the relationship between scientific claims and reality, the degree to which changes in scientific knowledge represent real “progress” in understanding reality, and the possibilities for science to ever come to full agreement about reality (Baberousse et.al., 2018). Hence, in addition to legitimizing science as a domain for consciousness-rousing and pleasure-seeking, and challenging limiting assumptions about how knowledge of the physical world can be gained, the curriculum also seeks to make students comfortable with the unknown and the potentially unknowable (Kumashiro, 2000).

To accomplish these aims, the curriculum is centered around scientific topics and questions usually not addressed in K-12 education. These represent areas in which the most up-to-date scientific theories stand in stark contrast to the portrait of reality given by standard K-12 science curricula and/or areas in which science seems to be at an impasse, suggesting that certain foundational notions may need to be re-examined. They likewise represent claims and wonderings that connect to fundamental and universal questions of existence – questions about possibility, about being, and about how we experience being. We see these areas of scientific research as being of special value in revealing fundamental assumptions upon which science as an epistemology rests, as well as tensions within that epistemology. We further see the epistemological tensions created by these topics, and the degree to which these topics connect to scientific knowledge that stands in contrast to what is conventionally “known” or questions where scientific knowledge falls short, as creating openings that invite other ways of knowing and other ways of seeing, using, and experiencing science.

Theories of Teaching & Learning
This curriculum is based on constructivist, sociocultural, and critical theories of teaching and learning. We wish for students to engage directly in knowledge-creation through inquiry and through social engagement, as well as to reflect critically about dominant discourses regarding knowledge-development. In addition, we embrace teaching and learning as holistic phenomena with affective and embodied aspects. This means that both teacher and students are invited to, and have a responsibility to, create and share understanding through physical, emotional, and internal responses. Eisner (1990) makes the point that “concepts are sensory in character” and are only attained “when we can imagine through sensory modalities what that concept is (p. 70).” Hubbard (2007) similarly points out that learners, as beings that are more than minds, make sense of their worlds physically and emotionally, as well as rationally (p. 47). In his argument for an aesthetic approach to teaching science, Dahlin (2001) offers a “phenomenological critique” of traditional science education which focuses exclusively on cognition and ignores the role of sensory experiences in knowledge-formation, and implicates this approach in the alienation of learners from the natural world. Thus, we see embodied and aesthetic approaches to learning supporting students’ greater understanding of core science concepts explored within the curriculum, while also serving our additional aims of enhancing students’ “wide-awakeness” and encouraging a view of science learning as a domain for pleasure-seeking. Hubbard makes this same point when she describes aesthetic experience as a “fusion of the whole being … capable of throwing off the covers bred by routine and making people wide awake to themselves and the world in which they live (p. 47)” and later argues, “embodied experiences do not only aid in the construction of knowledge; they also make this knowledge meaningful (p. 51).”
Our curriculum and its underlying pedagogical approach respond to students’ needs in several ways. First, as mentioned above, we invite and honor multiple approaches to knowledge creation and knowledge demonstration. This means that, in contrast to traditional K-12 science curricula, ours does not demand that students cut-off, quiet, or leave-at-the-door certain aspects of themselves (e.g. their bodies, their emotions, their philosophical or spiritual selves) in order to engage in learning. It means likewise that students can leverage various kinds of strengths in order to build and demonstrate understanding – for example, artistic or creative talents, strengths in self-knowledge and reflection, or abilities to empathize or take on different perspectives. By seeing the student holistically, and framing science education as, in part, education for the spirit or soul, our curriculum addresses what we believe are fundamental questions that drive all humans as learners, and adolescents in particular. As Miller and Moore (1999) argue:

By acknowledging soul we can face the “big” questions of life. These questions include, what is the nature of reality and truth? What is the purpose of life? Who am I and what is the nature of the human being? These questions can begin when as a child we look up into the cosmos and wonder about the nature of the universe. They continue into adolescence when we can begin to probe more deeply into the purposes of life. These are the questions that we come back to throughout our lives, and education should facilitate this process by examining how science … and other areas have explored and addressed these questions. A soulful approach … allows education to become deeply relevant to the lives of children and adolescents (p. 9-10).

In addition to serving students’ needs by considering various aspects of their selves; leveraging their diverse strengths as assets for classroom learning; and connecting science leaning to fundamental questions of life, being, and meaning which we believe all people, and
particularly adolescents, are in some way drawn to; we also respond to student needs by considering their experience in the context of traditional schooling. We see adolescence as a time when classroom experiences become especially narrow, with limited room for imagination and play, and so we have deliberately designed our curriculum in order to reclaim that room.

Likewise, we see our curriculum as responding to students’ needs by taking an equity-stance regarding what knowledge should be accessible to whom. Traditionally, certain science topics have been deemed too esoteric, controversial, difficult, or unnecessary for most students to learn, turning scientific knowledge in these domains into something like a luxury item, available only to those who study certain scientific disciplines at the post-secondary level. In contrast, this curriculum aims to make this knowledge available to any student interested in engaging with it.

**Socially Relevant Nature of the Curriculum**

**Relationship to Standards**

The curriculum is both grounded in and a critical response to the Next Generation Science Standards (NGSS) and the *Framework* on which the NGSS are based. The NGSS are both an important step forward in re-conceptualizing science education, and at the same time replicate certain narrow views about science and education more generally. The strengths of the NGSS on which we build include their emphasis on a constructive pedagogy in which students uncover scientific understanding through the development and application of core science and engineering practices, and the way in which the NGSS ground scientific knowledge development in natural phenomena which are likely to arouse students’ interest and curiosity. At the same time, because we believe there are ways of using science that do not reduce to simply developing explanations or engineering solutions (such as contemplating the natural world in order to create
greater wide-awareness or for simple pleasure), the curriculums expand on the “practices” of the NGSS in order to incorporate other ways of knowing and others facets of understanding.

What this means in practice is that we use elements of the NGSS Framework – including the Science & Engineering Practices, the Crosscutting Concepts, and the Disciplinary Core Ideas – as resources in our curriculum design, while also expanding on each of these to address what we see as their gaps and limitations. Likewise, we use the general formulation of the NGSS – in which practices, concepts, and core ideas or knowledge are all combined into a single standard – as a model and template for our own learning design. Because of the experimental nature of the curriculum – focused on cutting-edge scientific research usually not mentioned in K-12 science curricula, including the NGSS – we have had to supplement the NGSS. At the same time, we draw on and incorporate the NGSS in order to build the perquisite knowledge necessary for more complete engagement with the scientific theories and evidence this curriculum explores. While our aims are more expansive than those reflected in the NGSS, key aspects of our curriculum design also serve the foundational goals upon which the NGSS rest. This includes a models-based inquiry or phenomenon-based approach to the development and assessment of science knowledge, which meets the standards set by the EQuIP rubric for science lessons and units (a rubric promoted by the NGSS authors and designed to measure the extent to which curriculum and assessment materials match the vision and rigor of the NGSS).

**Education for All Students**

Just as we envision our curriculum as education for the whole person, we also see it as offering education for all learners. Greene (1993) explicitly ties aesthetic approaches to knowledge-creation to the work of creating more inclusive classrooms (and a more inclusive society). She writes:
Encounters with the arts can awaken us to alternative possibilities of existing, of being human, of relating to others, of *being* other … [and] can open new perspectives on what is assumed to be “reality,” … can defamiliarize what has become so familiar it has stopped us from asking questions or protesting or taking actions to repair (p. 214).

While we argue that encounter with the physical world and study of science (rather than the arts alone) also have a potential for awakening us to the “possibilities of existing,” we share Greene’s conviction that such awakening informs how we view and relate to others, and how we view taken-for-granted knowledge, and thus is foundational to creating a more inclusive science classroom and a curriculum for all students. Dewey (1922) makes a similar point when he argues that, “moral equality means incommensurability, the inapplicability of common and quantitative standards. It means intrinsic qualities which require unique opportunities and differential manifestations. .. Our best, almost our only, models of this kind of activity are found in art and science (p. 176).” This suggests that creating a just or morally equitable classroom does not mean applying the same standard to all students, but rather finding ways to value and make educative use of what is unique to each student. Our emphasis on subjectivity or individual meaning-making and choice in both learning and assessment activities is based in part on such a conception of equity and inclusivity. (See “Theories of Teaching & Learning” above for more on how we anticipate and address the needs of various types of learners.)

**Note to Potential Users**

There are a few things that teachers, administrators, and other potential users should have in mind when considering this curriculum. The first is that the aim of this curriculum is to expand, rather than replace, traditional goals for student achievement in science. As the above rationale explains, this curriculum centers around a desire for students to see science as a venue
for exploring personally-meaningful questions (about the nature, purpose, and possibilities of existence) for which there may be no final correct answers, and therefore invites students to engage in learning science in a holistic way, through their minds, bodies, and spirits. This pedagogical approach is adopted not only because it aligns with the curriculum’s expanded outcomes, but also because we believe it can increase student mastery of the traditional knowledge and skills of science, as well (see Theories of Teaching & Learning for more on the connection between aesthetic or embodied learning and conceptual understanding). Similarly, we see the curriculum’s explicit discussion of the philosophical underpinnings of science - which complicates common-sense views of the nature of science - as empowering students to be more critical in their consumption of science knowledge, but likewise developing them to be better at doing science themselves. Overall, we hope that potential users will view the central outcomes of this curriculum as complementary, rather than antithetical, to traditional aims of science education, such as being able to explain natural phenomena and engage in scientific inquiry.

This curriculum is likely to be of interest to users who share its convictions that education should serve the individual as a spiritual, physical, and intellectual being, and that students learn best when they can bring all facets of themselves to the classroom. Similarly, Science on the Fringes may be of interest in school environments that place an emphasis on the arts and creativity across content areas. In addition, users with a particular concern about increasing interest around, access to, and achievement in science for specific populations of students may wish to consider how this curriculum aligns to their goals. Adopting this curriculum means allowing all students at the high school level, regardless of prior achievement or coursework, to explore cutting-edge knowledge and questions that have the potential to arouse excitement for science in a way that the standard curriculum often fails to do. It also has the
potential for helping students who do not see themselves as strong in science to find ways to bring their own gifts and interests to learning science on a deep level.

Finally, while this curriculum is meant to be one which any high school can adopt - regardless of resources, structure, or population served - there are a few conditions which are most likely to ensure its success. First and foremost, a culture which welcomes experimentation and risk-taking, on the part of both teachers and students, is key. The curriculum lays out a few strategies for supporting such a culture within the classroom - such as offering the course on a pass/fail basis and using rubrics rather than letter grades for feedback - which require the backing of administration and parents. It is likewise important that teachers implementing this curriculum feel supported and trust both students and administrators. In addition, the curriculum is best suited for an environment where students can exercise some choice in their course selection; it is antithetical to the purpose and vision of this curriculum to place barriers on students’ access to it, by, for example, limiting it to certain academic tracks or requiring students to take other coursework as a prerequisite. We encourage potential users to consider these conditions as they determine if the curriculum is right for them.

Goals

Our curriculum attempts to push back against contemporary science pedagogies, which are based on the rigid, constraining and presumably objective standards and philosophies that are commonly attributed to science in schools. The overall goal is to activate the sense of curiosity and wonder about science that is stripped away from students by the time they reach high school. With neoliberalism’s broad reach as a hegemonic phenomenon that is fundamentally shifting how the process of learning is perceived and conceived (McCarthy et al, 2009), science education fell victim through the newly created New Generation Science Standards (NGSS).
Although these standards serve a neoliberal agenda through their increasing emphasis on engineering—the discipline that merges science and industry—and technical fixes, which fail to pay attention to the social or political implications of solving a certain scientific problem, they do contain elements and are built on frameworks that are conducive to freeing the student from the rigid shackles of a neoliberal science education (Weinstein, 2017; NRC, 2012). In the construction of the curricular goals, we adopt the NGSS Science and Engineering Practices, while supplementing these with additional practices that reflect the curriculum’s expanded aims.

**NGSS Practices:**

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

**Additional Practices of the Curriculum:**

- Self-awareness: we want students to think about science content in relation to themselves, and how they personally view the world and their existence within it.
- Guided imagination: we want students to merge rigorous scientific analysis with creative imagination; to ‘guide’ their imaginings of new possibilities in science with a foundation of formal scientific knowledge.
• Empathy: we want students to be open to different perspectives in science; not in a passive way, however, but in an empathetic and caring way where they truly listen to the perspective given and question it in relation to their own understandings.

Standards

The curriculum adopts NGSS that both align with the content of its four units and encourage some of the aforementioned practices that treat science as an ever-changing discipline of inquiry and exploration. In a few cases where the relevant content (for example, information processing in the brain) was not included in the high school NGSS, relevant middle school NGSS were adopted.

| HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. | HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. | HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation … to describe and predict the gravitational … forces between objects. |
| HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles and energy associated with the relative positions of particles. | HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. | HS-ESS1-2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. |
| HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. | HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. | MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. |
Essential Questions and Enduring Understandings

Further, we formed the following big ideas and essential questions around ways of knowing that stay true to the nature of science as a discipline of creative and imaginative inquiry.

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The diverse learner is not forgotten through these enduring understandings and essential questions, because we encourage through them an appeal to the affect–to curiosity and wonder amongst others–which are innate abilities that scholars argue exist within all types of students (Lee, 2017; Miller & Moore, 1999; Carr & Haldane, 2003). At the same time, we do not forget to
emphasize fundamental scientific skills, and we make sure to not sacrifice rigor when guiding students towards the big ideas and enduring understandings of our curriculum. We ask that the appeal to imagination and affect be grounded on the formal content discussed in class, so as to make sure that the student is learning about and engaging seriously with the different phenomena and ideas presented. Attaining the big ideas and enduring understandings of our curriculum through affect, imagination, curiosity and wonder can only occur if traditional/formal science learning happens en route.

**Organization**

*Science on the Fringes* is structured as a multidisciplinary elective course that can be taken over one semester and during the school day within a standard New York public school schedule (i.e. ~50 min. classes). The content of the *Science on the Fringes* is organized thematically, and contains four units across this semester-long curriculum, taking approximately one month each to complete. Each lesson or group of lessons will follow the 5E instructional model to promote student inquiry, drawing on learning strategies such as models-based inquiry, case studies, guided meditation, self-reflection, and embodied learning/play throughout in order to align with our curriculum’s aesthetic, creative and embodied learning goals.

Our curriculum designers strongly believe in removing as many barriers to this traditionally ‘inaccessible’ and ‘privileged’ scientific knowledge, which is often racially and socioeconomically stratified in the United States (Oakes, 2018; Nieto, 2018). For this reason, although our course will be aligned with NGSS standards, there are no prerequisites to this course. Additionally, our course will be offered as pass/fail. We believe removing the requirement for a lettered grade and making the course pass/fail will promote students' abilities to take personal and intellectual risks and engage in experimentation, as well as focus on learning
itself rather than the grade. In turn, students will be able to develop the core philosophical
knowledge and skills, such as creativity and imagination, while also being able to understand the
content more deeply. The teacher’s primary role in this curriculum will be of facilitator, public
intellectual, role model, and participant in the creation of a third space of knowledge, learning,
and play (Giroux, 1994). The teacher’s role will be explicitly and publicly defined and
constructed in the beginning of the course via establishing norms for the space and shared
learning experiences through transparent and open communication. Teachers will model
dialogue that promotes transparency, openness, equality, and respect with students in an ongoing
way.

Our curriculum designers wish for the physical classroom to be set-up as a collaborative
space. We envision teachers curating the physical classroom environment in ways that promote
non-hierarchical power dynamics and ongoing open dialogue between teacher and student, as
well as students. This can occur for example through arranging the room in a non-lecture
based interactive classroom seating structure, such as chairs in a circle or allow students to sit
comfortably on the floor or where they most desire. We aim for the organization of the physical
space to allow students to feel that they have the opportunity to drive the course forward through
and with their (and others) minds, bodies, spirits, interests, curiosities, and/or current events, in
service of a truly inquiry-based and communal curriculum that celebrates the shared mystery and
joy of diving into the ‘big questions’ of life.

The classroom dynamics and environment will be extremely important elements of
consideration as we seek to establish a strong learning community built around trust, which will
help foster additional elements of our curriculum such as sensory learning and making
personalized meaning of learning. Students will be equal contributors to the production of
knowledge, i.e. knowledge creators, and bring outside knowledge and internal values into the classroom. Teachers will build-in discussion-based time with classmates in order to revive imagination and creativity, being sure to set norms around discussion and the purposes of activities such as ‘open debate’ in order to maintain a trusting and safe community as we seek to bring students’ multi-layered, authentic and holistic identities into the classroom. We aim to create space and an environment that allows teachers and students to feel that they can and are welcome to open up about their subjective experiences, and use that as a plane of knowledge creation, emphasizing our values of sensory, experiential, and holistic curriculum that goes beyond the modes of knowledge traditionally privileged in the science curriculum (i.e. factual or rational). Within our daily lessons, teachers will acknowledge, probe or actively question, and address students’ prior conceptions and experiences - regarding what science is/isn’t, what happens in a science class, what it means to do science / be good at science, what learning is, etc.

Importantly, we also envision the teachers role modeling a sense of play and creativity throughout the curriculum, which will allow both teachers and students to openly explore the nature of unknowability in the topics each week. Certain practices or activities will be used on regular basis - e.g. reflection, creativity/making, and open-discussion, as to continuously reorient students towards our aims of an aesthetic, creative, and holistic curriculum (Eisner, 1990). These organizing routines derive from our values of injecting students with a sense of play that can often become lost in the secondary level (Miller & Miller, 1999).

Consistency across our curriculum will also be achieved by way of following a similar structure or progression throughout each unit, as well as how we tie to one unit to another through a culminating performance task which requires students to combine learning from multiple units. Each unit of study will refocus students on affective and creative outcomes by
way of having a consistent reorienting ‘introductory opening’ exercise. The ‘introductory opening’ led by teachers will ask students to approach each unit with a reconsideration and re-orientation away from traditional ways of knowing scientific content, and will thus become an overarching principle and staple exercise in our curriculum. Day to day teachers will also continuously realign students towards these principles in each lesson, reminding students why and how this science class has different aims than a traditional science classroom.
# Content Overview

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<td>Combine knowledge gained and understandings uncovered in two or more units to create some sort of creative representation of the <em>possibilities</em> opened by what we currently think we known, as well as what is left unknown or unknowable. This representation may take the form of a piece of science fiction, whether a short story, script for a play or movie, video/film, or video game. It may also take a form not typically associated with “science fiction,” such as poetry or visual art. Regardless of form, it should also include a self-analysis of the representation related to the essential questions and enduring understandings of the curriculum.</td>
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| 4 | “Am I a Robot?”: The Science of Consciousness | Is consciousness real? / Is consciousness an illusion, or the only thing we can ever know to be real?  
Is it possible to have a complete, objective description of subjectivity?  
Must everything that emerges from the physical world be explainable through physical causes?  
Is the blue I see the same as the blue you see? How do you know? Could we ever know?  
How do I know you’re not a robot? How do I know I’m not a robot? | All scientific theories and inquiries into consciousness rest on certain (explicit or implicit) philosophical underpinnings regarding what consciousness is / what its essential characteristics are.  
For something to be “real” is not necessarily the same thing as for it to be testable or verifiable (and vice versa).  
While we can measure or observe certain physical phenomena which we see as correlated to consciousness, we cannot measure (or observe in another) consciousness itself. | 4 weeks |
|---|---|---|---|
| 5 | Culminating Task | What is the difference between the unknown and the unknowable? And is anything ultimately unknowable?  
What is the relationship between reality, science, and the self?  
Could there be a single ultimate and verifiable theory to completely describe the universe? | There is legitimate debate and uncertainty regarding why some things about our universe are unknown, and whether they will ever be known.  
When science makes claims about reality, it is based on certain assumptions about reality which are not themselves testable/provable using science.  
Theories that describe the universe do not necessarily need to be complete. | 1 week |
### Big Ideas and NGSS Standards

**What else is out there? Dark Energy & Dark Matter**

**Essential Questions:**
- How do we know what is out there?
- Will we ever know everything that exists in the universe?
- What does it mean to be invisible?

**Enduring Understandings:**
- For something to be known to exist (by us), it must be in interaction with something else. We can only know the existence of something through its interaction with something else.
- While scientists attempt to create an ever-more-complete picture of the universe as a whole, gaps in our knowledge and understanding of the cosmos continue to be revealed, and it is possible some aspects of the universe will always evade our knowledge and understanding.
- “Invisibility” as a property

### Core Knowledge & Skills

1. **Content Knowledge**
   - Mathematical/causal relationships between mass, distance, and force of gravity; and between gravitational force and speed of a body in orbit
   - Mathematical/causal relationships between energy, momentum, force, mass, and acceleration
   - Relationship between balanced/unbalanced forces and resulting motion
   - Doppler effect: redshift and blueshift as evidence of light’s motion
   - Relationship between mass of a star and light generated (as means of determining amount of mass in a galaxy)
   - Big Bang theory - history of, evidence for, major claims of...
   - History behind development of ideas of dark matter and dark energy, including abandoned ideas (e.g. anti-gravity)
   - Alternatives to dark energy and dark matter as explanations for relevant phenomena (e.g. idea of variable / changing “constants,” “anthropic” explanation for value of cosmological constant, modifications to general relativity, etc.)

### Performance Task

**Living Timeline:** Create a timeline that captures important moments in the history of scientific thought that led to the current status of dark matter and dark energy as recognized potential explanations. Include various branching points, ‘dead-ends’, and reversals, in order to demonstrate the tentative, nonlinear or iterative, and contentious way in which “paradigm shifts” unfold, as well as the way that various scientists’ responses to new, contradictory evidence often open certain possibilities previously unimagined, while leaving other avenues apparently closed.

### Sample Learning Activities

- Labs: Use PhET simulation to analyze relationships between mass, distance, and gravitational force; use string simulation to analyze relationship between gravitational force and speed. Connect two simulations to relate observed speed and expected mass, and, for a given galaxy, compare this to proposed mass (based on light given off by stars) to justify possibility of dark matter.
- Labs: Balloon simulation to demonstrate expansion of space. Physical
depends as much on the subject attempting to view something as it does on the object being viewed. To say something is “invisible” reveals as much about one’s own abilities to see as it does about the object in question.

**NGSS Standards:**

**HS-PS2-1.** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

**HS-PS2-2.** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

**HS-PS2-4.** Use mathematical representations of Newton’s Law of Gravitation … to describe and predict the gravitational … forces between objects.

**HS-PS3-2.** Develop and use models to illustrate that energy at

<table>
<thead>
<tr>
<th>2- Philosophical Knowledge</th>
<th>3. Skills</th>
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</thead>
<tbody>
<tr>
<td>1) Indirect nature of measurement and calculation, and how the indirect nature of measurement creates room for error or dependence on certain assumptions to draw conclusions, leaving room for alternate explanations</td>
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<tr>
<td>2) Relationship between mathematics and science - history of how quantifiability became central to scientific explanations, how “making the equations work” is still central to how/why scientists propose or reject new theories, including proposing existence of “stuff” that there is otherwise no evidence for</td>
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<td>3) Kuhn’s notions of “normal science” and “paradigm shift”</td>
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<tr>
<td>a) During a “paradigm shift,” some assumptions get questioned, challenged, and abandoned, while others remain. The new “normal science” which emerges depends not only on the evidence scientists are responding to, but the decisions made about which assumptions to challenge and which to preserve.</td>
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<tr>
<td>1) Analyzing and interpreting data</td>
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After completing the initial timeline, create an “imagined” timeline (adding to the old one in a way that visually distinguishes what happened vs. what could have happened or could still happen). This “imagined” timeline can project into the future, imagining what new evidence or new perspectives might emerge and their impact on current scientific thinking regarding the existence/nature of dark matter and dark energy. This “imagined” timeline can also create alternatives in the past/present, speculating on how the status of various hypotheses within the scientific community would have been different if different amount of energy had been different). Investigations to demonstrate role of energy in acceleration.

Explore proposed ideas of what dark matter is and brainstorm own ideas about what dark matter could be or what they would like it to be (i.e. What could be hiding, undetected by us, in the space between stars, holding those stars together as they move?). Create poetry based on dramatization of how scientists believe Big Bang would have proceeded given differences in initial conditions (students act out with their bodies what would be different if amount of energy had been different).
the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

**HS-PS3-5.** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**HS-ESS1-2.** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

2) Using mathematics and computational thinking
3) Constructing explanations (for science) and designing solutions (for engineering)
4) Engaging in argument from evidence
5) Obtaining, evaluating, and communicating information
6) Perspective-Taking
7) Empathy
8) Self-Knowledge
9) Counterfactual thinking / developing and using hypotheticals / imagining alternatives

Reflection question: What determines the new “common sense” or “normal science” that emerges from a paradigm shift?

Evidence had emerged and/or different assumptions were challenged vs. preserved.

Explorations in the Dark - students attempt to determine what is present in a completely dark space (e.g. by walking around classroom with lights off) and then reflect on strategies used and limitations of those strategies. Relate this to information gained from various media on how scientists explore the cosmos.

| 2) Using mathematics and computational thinking | 3) Constructing explanations (for science) and designing solutions (for engineering) | 4) Engaging in argument from evidence | 5) Obtaining, evaluating, and communicating information | 6) Perspective-Taking | 7) Empathy | 8) Self-Knowledge | 9) Counterfactual thinking / developing and using hypotheticals / imagining alternatives | Evidence had emerged and/or different assumptions were challenged vs. preserved. | Reflection question: What determines the new “common sense” or “normal science” that emerges from a paradigm shift? | Explorations in the Dark - students attempt to determine what is present in a completely dark space (e.g. by walking around classroom with lights off) and then reflect on strategies used and limitations of those strategies. Relate this to information gained from various media on how scientists explore the cosmos. |
**Enduring Understandings:**

There is room for subjectivity and imagination when thinking about the nature of reality.

There is an ambivalence on whether or not there can be an ultimate theory for describing the universe.

Framing your investigation of reality affects the theories on reality that we end up developing.

**Essential Questions:**

Is it possible to develop a subjective understanding of the universe through imaginatively reconciling the contradicting worldviews of relativity and quantum physics?

Is there a difference between measuring and observing? What does the existence or non-existence of this difference say about how we think of reality?

**NGSS Standards:**

1. The universe is said to be governed by a number of fundamental ‘forces’ that determine how things move, interact and transform through space.
   a) What are forces? Can the assumption that forces govern the universe be challenged?

2. Four fundamental forces are thought to exist in the universe: gravitational force, electromagnetic force, strong nuclear force and weak nuclear force.

3. Using the equations of relativity—developed by Einstein in the early 1900’s—to describe the movements of stars, galaxies, nebulas, among other really large objects in the universe, proved that relativity is a valid model for describing the force of gravity.

4. Observations and experiments done on atomic and subatomic particles showed that the forces of electromagnetism, strong nuclear force and weak nuclear force are governed by a completely different type of physical phenomenon, which quantum physics is a valid model for describing.

5. Quantum and relativity both attempt to explain the physical universe using models: quantum is a model for explaining the really small, relativity is a model for the really large.
<table>
<thead>
<tr>
<th>HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.</th>
</tr>
</thead>
</table>
| 6) Quantum and relativity are weird:  
   a) Relativity introduces the idea that, on a massive enough scale, space and time become dependent on and thus distort each other.  
   b) Quantum physics introduces the idea that, on a small enough scale, an object’s physical properties are probabilistically determined. Double-slit experiment, for example, shows how light can be understood as both a wave and a particle. Using electrons in this experiment without knowing which slit they pass through produces the same pattern that light shone on a slit produces.  
| 7) Relativity based on a determinism and continuity to how objects move through space  
| 8) Quantum based on the fact that the physical properties of objects at the atomic/subatomic scale are not continuous, but exist in discrete states.  
| 9) Quantum and relativity represent completely different interpretations of reality, yet are both equally valid.  
| 10) Quantum entanglement is an example that proves this inherent difference  
| 11) Quantum mechanics (specifically its deterministic nature) changes based on observations.  
| 12) The search for a *Theory of Everything* change, and why? To what extent do you believe your own theory? What are its strengths and weaknesses? What did you most enjoy about this task? What did you find most challenging?  
| Thought experiments for relativity (traveling near the speed of light)  
| Diffraction and double-slit experiment simulations |
2- Philosophical Knowledge
1) Two fundamentally different theories to describe the universe means that there can be subjectivity at this point in time for thinking about the nature of the physical universe.
2) Since scientists are completely baffled by how to reconcile the two theories, and in the spirit of science as a space for imaginative yet scientifically grounded inquiry, creativity and imagination is an acceptable attempt to reconcile them.
3) Unit relies heavily on phrases such as “Can be understood”, “is said to be”, “are thought to exist”, etc. to reaffirm that these theories are simply models to understand how things work. They are not representative of some truth or reality about the nature of the physical universe.

3. Skills
1) Guided imagination
2) Critical thinking
3) Self-knowledge
4) Empathy for different perspectives
5) Embodied learning
6) Constructing explanations
7) Arguing with evidence
8) Communicating information scientifically
**Who's really in control? Determinism and the Brain**

**Enduring Understandings:**
Assumptions around the depth of our free will determines current Western medical practices.

**Enduring Questions:**
Can free will be explained solely through brain science, or are there explanations beyond human biology that we will ever reach?

By what mechanisms do humans heal? What influences our ability to heal our bodies?

Can healing be explained solely through biology? What is unknown about the mechanism by which we heal?

Are there irreducible qualities about biological phenomena that cannot be explained?

**NGSS Standards:**
HS-LS1-3. Plan and conduct an

<table>
<thead>
<tr>
<th>1-Content Knowledge</th>
<th>Free Write &amp; Skit:</th>
<th>Case Study:</th>
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</table>
| 1) Human brain anatomy, systems and mechanisms  
   a) By what mechanism do thoughts arise?   
2) Human body systems  
   a) Mechanism of regulation system ie. Homeostasis  
   b) Homeostasis disruptions during illness  
   c) Human body as an electrical energy system  
3) The entire Universe is made up of energy  
   a) Observing Phenomena - ex. Nature, sorting of m&m’s based on different frequencies/vibrations  
4) Free Will  
   a) Different theories of free will  
   b) The universe is probabilistic versus deterministic (related to quantum mechanics)  
   c) Brain activity has been shown to precede our conscious thoughts (“readiness potential, cross-modal synchronization)  
   d) Ex- hypnosis |
| Students will contemplate the following question: *Do we or don't we have free will?*  
Next, they pick the opposite opinion to their original answer!  
Then, they will free-write their response around the question: *What would be different about your life or experiences if this were true?* |
| Read/listen/watch various personal narratives and medical experiments around complementary and alternative medicines to heal illness and recover from pain.  
Students will engage in a fishbowl discussion about the role of expectation, belief, and the biological mechanisms by which patients were/were not able to alleviate pain and/or heal from illness. Teachers will prompt students to use content knowledge around the human body systems, studies on free will, consciousness, and the medical nature of healing in their |

**Free Write & Skit:**
Students will contemplate the following question: *Do we or don't we have free will?*

Next, they pick the opposite opinion to their original answer!

Then, they will free-write their response around the question: *What would be different about your life or experiences if this were true?*

**Story Design** *(Optional):*
In order to prepare for their skit, students will create a story around a singular moment in time, going ‘backwards in time’ to analyze a series of decisions that may have lead to alternative outcomes.

**Case Study:**
Read/listen/watch various personal narratives and medical experiments around complementary and alternative medicines to heal illness and recover from pain.

Students will engage in a fishbowl discussion about the role of expectation, belief, and the biological mechanisms by which patients were/were not able to alleviate pain and/or heal from illness. Teachers will prompt students to use content knowledge around the human body systems, studies on free will, consciousness, and the medical nature of healing in their
<table>
<thead>
<tr>
<th>Investigation to provide evidence that feedback mechanisms maintain homeostasis.</th>
<th>Medicine</th>
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<tbody>
<tr>
<td>MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.</td>
<td>6) Healing</td>
</tr>
<tr>
<td>MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</td>
<td>a) Brief overview of the biological mechanisms of healing</td>
</tr>
<tr>
<td><strong>Philosophical Knowledge</strong></td>
<td>b) What factors is healing impeded by</td>
</tr>
<tr>
<td>1) Contemplating the mind-body connection through embodied experience (guided meditation), case studies, and a fishbowl activity</td>
<td>c) Complementary and alternative medicines (CAMs) – i.e., homeopathic remedies</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td>d) Ex’s - claims of healing that cannot be explained scientifically</td>
</tr>
<tr>
<td>1) Asking questions</td>
<td>Shamanism</td>
</tr>
<tr>
<td>2) Critical analyzing information</td>
<td>a) Ancient origins of healing illness</td>
</tr>
<tr>
<td>3) Empathy for different perspectives</td>
<td><strong>Perspective</strong></td>
</tr>
<tr>
<td>4) Constructing explanations</td>
<td>1) Engaging in argument from evidence</td>
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<tr>
<td>5) Obtaining, evaluating, and communicating information</td>
<td>2) Self-knowledge, internal awareness, and meta-cognitive reflection</td>
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<tr>
<td>6) Perspective-taking</td>
<td><strong>Self-Reflection</strong></td>
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<tr>
<td>7) Obtaining, evaluating, and communicating information</td>
<td>1) Students can feel free to perform that certain moment of time or alternative event pattern they have written about during their free write in small groups or to the whole class. If students do not feel comfortable performing, they can turn in their creative work in an alternative format.</td>
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<tr>
<td>8) Engaging in argument from evidence</td>
<td><strong>Discussions</strong></td>
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**“Am I a Robot?” The Science of Consciousness**

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th>1-Content Knowledge</th>
<th>Propose an original thought experiment (see “Philosophical Knowledge” for examples of classic thought experiments in consciousness) meant to illuminate either a question or claim related to consciousness.</th>
</tr>
</thead>
</table>
| Is consciousness real? / Is consciousness an illusion, or the only thing we can ever know to be real? | 1) Evolutionary hypotheses regarding the development of consciousness  
   a) Background evolutionary knowledge: Darwin’s theory of evolution by natural selection, “fitness,” mechanisms that drive evolution of traits, homologous evolution, evolutionary “byproducts” | Develop a creative representation of this thought experiment. |
| Is it possible to have a complete, objective description of subjectivity? | b) Proposals on the potential “functionality” of consciousness and relation to evolution | Make an argument using your thought experiment (this may be an argument in which you take a position on a core question of consciousness, in which you argue for what else would need to be known or resolved first, or in which you argue for the un-answerability of the question itself). |
| Must everything that emerges from the physical world be explainable through physical causes? | c) Research on other species that inform evolutionary arguments regarding the development and function of consciousness - fish, cephalopods... | Explain the relevance |
| Is the blue I see the same as the blue you see? How do you know? Could we ever know? | 2) Neurological hypotheses regarding the relationship between consciousness and the brain  
   a) Background neurological knowledge: basic knowledge of brain anatomy and physiology, how information is processed in the brain, various methods for stimulating and observing brain activity | Book Groups to read and discuss one of several books on consciousness: The Diving Bell and the Butterfly; Other Minds: The Octopus, the Sea, and the Deep Origins of Consciousness or The Soul of an Octopus: A Surprising Exploration into the Wonders of Consciousness; How to Change Your Mind: What the New Science of Psychedelics Teaches Us About Consciousness, Dying, Addiction, Depression, and Transcendence; (see https://www.theguardian.com/books/2017/sep/20/top-10-books-about-consciousness for additional book ideas). |
| How do I know you’re not a robot? How do I know I’m not a robot? | b) Categories of experiments which inform neurological theories, what kind of evidence is gathered by each type, and how it informs theories: brain stimulation, brain... |                                                                                                                                 |

**Enduring Understandings:**

All scientific theories and inquiries into consciousness rest on certain (explicit or implicit) philosophical underpinnings regarding what consciousness is / what its essential characteristics are.

For something to be “real” is not necessarily the same thing as for it to be testable or verifiable (and...
While we can measure or observe certain physical phenomena which we see as correlated to consciousness, we cannot measure (or observe in another) consciousness itself.

**NGSS Standards:**

**MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

**HS-LS4-2.** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

3) **Possible “tests” of consciousness:**
   - a) Zap and zip (medical)
   - b) Turing test (theoretical)
   - c) CAPTCHAs used on websites

4) **Systems theories and their relationship to theories of consciousness**
   - a) Global neuronal workspace (GNW)
   - b) Integrated information theory (ITT)

5) **Altered States of Consciousness and their relationship to brain activity / other observable phenomena:**
   - a) Meditation / mindfulness
   - b) Mind-altering drugs / Psychedelics
   - c) Dream states

**2- Philosophical Knowledge**

1) **Various terms and definitions:**
   - consciousness, subjectivity, awareness, awakeness, sentience, qualia - potential distinctions between these terms (what qualities of experience does each emphasize) and relationship to relevance of various tests and theories of consciousness

2) **Systems thinking and idea of “emergence” / emergent properties**

(or lack thereof) of some of the scientific claims, evidence, and lines of inquiry related to consciousness we have discussed, given your thought experiment and resulting argument.

Alternative choices:
Rather than a developing a thought experiment, students can choose one of the following other options (and go through a similar process / create a product that accomplishes similar criteria):

- Propose a “test” for consciousness (How would you know that you, or some other being, was conscious?) (see “Content Knowledge” for examples of tests)

(scaffolding / differentiation: for some students, a film or Podcast option may be more appropriate; film options include: *Bladerunner, To Be,* and *Waking Life*)

Jigsaw Activity: members of different book groups meet to discuss book themes and compare and contrast understandings related to consciousness based on these themes.

Guided meditation activities, followed by debrief of student experiences during these activities (sample debrief question: how could we “test” what you experienced?).

Participation in
<table>
<thead>
<tr>
<th><strong>HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</strong></th>
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<tbody>
<tr>
<td>3) Major philosophers who have contributed to philosophy of consciousness and their key ideas and/or “problems” they created or identified: Descartes (mind-body problem), Chalmers (“hard problem” of consciousness), Nagel, Parfit, Jackson, Dennett, Churchland</td>
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<td>4) History of dualism within Western thinking and potential alternatives to dualistic thinking (e.g. alternatives to mind-body dualism, objectivity-subjectivity dualism)</td>
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<tr>
<td>5) Use of thought experiments in philosophy, and specific thought experiments related to key philosophical questions of consciousness</td>
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<tr>
<td>a) “Mary’s room” (Jackson)</td>
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<td>b) Tele-transportation paradox (Parfit)</td>
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<td>c) Philosophical zombie (Chalmers)</td>
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<td>d) Chinese room (Searle)</td>
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**3. Skills**

1) Asking questions  
2) Developing and using models  
3) Planning and carrying out investigations  
4) Analyzing and interpreting data  
5) Constructing explanations and designing solutions  
6) Engaging in argument from evidence  

- Develop a guided meditation or reflective exercise meant to make its user more aware of his/her own consciousness

**Virtual Reality and/or other type of simulation activity.**

Field Trip: Arrange field trip to lab and/or hospital to either witness, or ideally participate in, brain stimulation and/or brain imaging.

“Virtual” Field Trip: Arrange to interview one or more researchers at the Center for Consciousness Studies, University of Arizona.

Optional Volunteering Activity: volunteering on a ward for patients in vegetative states and completing a reflection on the experience.
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<td>7)</td>
<td>Obtaining, evaluating, and communicating information</td>
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<td>8)</td>
<td>Perspective-taking</td>
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<td>9)</td>
<td>Empathy</td>
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<td>11)</td>
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Assessment Philosophy and Overview

The approach to assessment of this curriculum is grounded in a few key premises. First, we take an advocacy approach to assessment, as defined by Fennimore (1997), meaning that we aim to develop and implement an assessment system which “enhance[s] … the current educational opportunities [and] open[s] … doors to the future development and education (p. 242)” of all students. Second, given our belief that education is for the whole person, rather than the calculating mind alone, we are mindful of the emotional implications of assessment practices, and take responsibility for considering and addressing those as a part of our curriculum design. Likewise, we recognize that the nature of this curriculum – both given the topics covered, which are usually excluded from K-12 science curricula because they are deemed too esoteric or “advanced,” and given the expanded aims we seek for students – requires experimentation and risk-taking on the part of both students and teacher. It is thus imperative that assessment systems be designed in ways that encourage and reward such experimentation and risk-taking. Finally, we believe in the premise of assessment for learning that is embedded fully within learning. That is, rather than drawing a strong distinction between tasks for learning and tasks for assessment, we see many of the activities and prompts of the curriculum serving both functions simultaneously, as students make attempts, engage in dialogue about what they have thought and done, receive feedback from teacher and peers, and revise or further their work. This learning-embedded approach to assessment functions similarly to what Oakes, et. al. (2018) call “interactive assessments (p. 268-269)” as they argue, such an interactive or learning-embedded approach allows both teacher and students to make rapid course-corrections to improve the quality of learning and of student demonstration of learning.
Several aspects of the curriculum assessment system are fundamental, given the premises laid out above. First and foremost, this course is offered on a Pass/Fail basis. Students will receive rubric scores on specific assignments, but these scores will not be tied to an evaluative letter-grade system. We see this as essential to encouraging experimentation for all participants, as well as ensuring that risks taken within the classroom by teacher or students do not equate with the risk of foreclosed future educational opportunities. We also hope that the Pass/Fail nature of the course and non-grade-based scoring will support students and teachers to focus more on the feedback gained through assessment, rather than the potentially harmful evaluative messages communicated by assessment.

In addition to making the course Pass/Fail, our approach to assessment includes the use of performance tasks that invite more personal decision-making or subjective meaning-making on the part of students, while still assessing core scientific knowledge and skills. The curriculum likewise includes performance tasks in which students can make choices about the form in which they communicate their understanding. The use of inquiry cycles to structure learning activities (see learning experiences bank for more on this) creates a system in which assessment is embedded into learning. The process of developing initial hypotheses or models in response to phenomena and continually revising models based on evidence or understanding gained creates natural opportunities for diagnostic, formative, and summative assessment in the context of learning. The regular use of individual reflection activities provides a similar opportunity for gauging changes in student thinking over time, as well as assessing aspects of students’ experiences of the curriculum and development in response to the curriculum that go beyond their mastery of technical science knowledge – such as their affective response to knowledge and activities, increased awareness of their own philosophical perspectives, and changes in their
critical understanding of the nature of science. While performance tasks, model-making within inquiry cycles, and reflection activities provide the core of the curriculum’s assessment system, they are supplemented by other forms of assessment, such as traditional quizzes and tests of formal knowledge acquisition, academic prompts as scaffolds to performance tasks, and informal checks for understanding and observations within the context of ongoing classroom instruction.

**Sample Assessment Tools**

**Culminating Task**

**Description (for teacher):** Students will combine knowledge gained and understandings uncovered in two or more units to create some sort of creative representation of the possibilities opened by what we currently think we know, as well as what is left unknown or unknowable. This representation may take the form of a piece of science fiction, whether a short story, script for a play or movie, video/film, comic, or video game. It may also take a form not typically associated with “science fiction,” such as poetry or visual art. Regardless of form, it should also include a self-analysis of the representation that interprets the work against the essential questions and enduring understandings of the curriculum.

**Examples of art works that incorporate scientific possibilities (some of these are introduced in Unit Zero to provide direction; others can be used at the teacher’s discretion):**

- Poems: “Aniara,” by Harry Martinson; “The Migration of Darkness,” by Peter Payack; Amy Catanzano’s quantum poetry
- Music/Audio: Space Oddity, by David Bowie; “Everything is Alive” podcast
- Movies: Solaris (1976), 2001: A Space Odyssey, Blade Runner and Blade Runner 2049, Altered States, Moon, Looper, Ex Machina, Arrival, Inception
- TV: Twilight Zone, Fringe, Black Mirror
Prompt (for students):

**Your Goal:** To convey a personal meaning to an audience through an artistic representation that in some way reflects the possibilities opened by the scientific terrain we have covered this semester. The possibilities your work communicates may be those opened by the evidence and scientific theories and hypotheses discussed in this course, as well as those opened by related problems, puzzles, and unanswered (unanswerable?) questions we have explored.

**Role:** For the purposes of this task, you are both artist and artistic interpreter.

**Audience:** You will present this work to your classmates, as well as to other invited guests (students, teachers, family members, friends, etc.) at a showcase at the end of the semester.

**Product:** You are asked to create a work of “science fiction,” loosely defined, that is, a work that draws on knowledge and ideas from science and repurposes them in creative or imaginative ways to achieve an artistic purpose. This may include written fiction (such as a short story), a film or play script, a piece of video or film, a poem, a piece of visual art (such as a painting or sculpture), a video game, a comic, or work in alternative medium.

In addition, you should complete a self-analysis of your work. This self-analysis should take the form of a written review or summary of the work (~2-3 pages in length). The self-analysis should make explicit the scientific questions, evidence, and ideas being drawn on, and the specific ways they are represented and used in the artistic work. The self-analysis should also
make an argument for how the representation reflects or adds to discussion of one or more of the following questions:

- What is the difference between the unknown and the unknowable? And is anything ultimately unknowable?
- What is the relationship between reality, science, and the self?
- Could there be a single ultimate and verifiable theory to describe the universe?

Standards/Criteria:

Both the artistic representation and the accompanying self-analysis should:

- Synthesize knowledge and understandings gained from at least two of the course units
- Reflect both current scientific explanations and evidence about these subject areas and questions that remain unanswered.
- Discuss the possibilities opened by either what is “known” or what is “unknown.”
- Communicate a specific, personal message or meaning in relation to these possibilities.
- Meet the criteria of the course’s general performance task rubric.

Pre-Assessment Task

Description (for teacher): The purpose of this task is to introduce the ways of thinking and forms of engagement that we intend to develop for students throughout the course of our curriculum. This means that it should take place in the beginning of the semester period in which the curriculum is to be implemented. The idea is to dedicate a class session where students are asked to collaboratively answer some simple questions about the nature of imagination, perceptions of what science is, what science can be, and perhaps even engage in a physical activity that allows them to think about the answers to these questions through their bodies, or through the physical space of the classroom. The task should begin upon students entering the
SCIENCE ON THE FRINGES

classroom, where they will be asked to rearrange its layout into a group seating layout. If the
class is already arranged that way, they will be asked to rearrange it again to a different group
seating layout. This is done as a pretext for the ensuing discussions on imagination and
creativity, which push back against the stasis we believe is given to scientific thinking in K-12
classrooms. This falls under the engagement part of the 5E’s model we are using, where
“students’ prior knowledge is accessed and interest is engaged in the phenomenon”.

Prompt (for students):

**Your Goal:** Throughout this class session, you will be presented with several questions that you
will discuss with your classmates in small groups. For every question presented, you are asked to
produce three ideas that answer it. There is no right answer here, as the questions are simply
meant to stimulate your senses of inquiry, curiosity, imagination and creativity. The questions
include “What does it mean to imagine?” “How is science used in society?” “How is science
used by you?” and “What is science to you?”

**Product:** After each question, each group will be asked to present their three ‘answers’ in a
variety of ways, some of which will culminate in an inter-group discussion about what answers
they particularly liked (and why), which they disagreed with, etc. For questions such as “How is
science used in society?” and “How is science used by you?”, the groups will merely present
their three ideas, which you must have written on a piece of paper and stuck (using tape) to one
of the walls closes to you. The teacher will ask you clarifying questions if they have any. For the
more open questions “what does it mean to imagine?” and “What is science to you?”, you will
come up with the answers and stick them to the wall near your other answers, but instead of
merely presenting them, this time you will walk around the classroom and see what other groups
wrote and then engage in a class discussion about your different answers. Were there any similarities in the types of answers given? Are there any answers/ideas that you would like clarification about? The last discussion will involve thinking about the purpose of this activity. What did you learn from hearing the different answers and ideas to these questions? What surprised you? Do you find yourself disagreeing with any of them? Agreeing?

**How the teacher will use this information:** The teacher should use this information to gauge how students currently think about science, imagination, the role of imagination in science and, the relation of science to themselves and society. This will allow the teacher to perhaps more concretely address student misunderstandings and struggles throughout the semester when such ideas are touched upon or interrogated more explicitly. Students will perform this activity again during the semester so the teacher should record the students’ behavior, movement, and ideas (for example, by taking pictures of student responses) so that, as students engage with it again, both teacher and students can compare to previous responses and reflect on changes.

**Performance Task Rubric**

<table>
<thead>
<tr>
<th>Points</th>
<th>Content Knowledge</th>
<th>Philosophical Knowledge</th>
<th>Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Illustrates a mastery of content knowledge, particularly key ideas in the unit, and uses nuanced content knowledge to expand or deepen their understandings within the performance task.</td>
<td>Illustrates a mastery of philosophical knowledge, particularly key ideas in the unit, and uses nuanced content knowledge to expand or deepen their understandings within the performance task.</td>
<td>Illustrates a mastery of skills, particularly key ideas in the unit, and uses nuanced content knowledge to expand or deepen their understandings within the performance task.</td>
</tr>
</tbody>
</table>

**Note to Teachers:** This rubric may need to modified due to the experimental nature of these assignments. Adding specific and relevant language based on the performance task may help in the analysis of student work.
<table>
<thead>
<tr>
<th>Score</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Illustrates an understanding of content knowledge needed to explore key ideas in the unit, though does not attempt to use that knowledge to expand or deepen their understandings further in the performance task.</td>
</tr>
<tr>
<td>1</td>
<td>Illustrates inconsistent, inaccurate, or vague attempts to engage in the understanding of content knowledge needed to explore key ideas in the unit, nor attempts to use that partial knowledge to expand or deepen their understandings further in the performance task.</td>
</tr>
<tr>
<td>0</td>
<td>Does not attempt to engage in the understanding of content knowledge needed to explore key ideas in the unit; nor attempts to engage in the creation of a performance task.</td>
</tr>
</tbody>
</table>
Learning Experiences Bank

**5E Lessons:** The 5E lesson model, originally developed by BSCS Science Learning and now adopted by many science educators and curriculum designers, is a general model for structuring lesson plans to promote student inquiry. The 5 “E”s are Engagement, Exploration, Explanation, Elaboration, and Evaluation. The BSCS website explains the purpose of each phase:

- **Engagement** – students’ prior knowledge accessed and interest engaged in the phenomenon
- **Exploration** – students participate in an activity that facilitates conceptual change
- **Explanation** – students generate an explanation of the phenomenon
- **Elaboration** – students’ understanding of the phenomenon challenged and deepened through new experiences
- **Evaluation** – students assess their understanding of the phenomenon

(BSCS Science Learning, n.d.)

**Models-Based Inquiry Cycles (Phenomenon-Based Learning):** Models-based inquiry is similar to, but somewhat more specific and developed than, the 5E lesson structure. It is an instructional approach based on two core premises: 1) that science instruction should mirror scientific inquiry processes; and 2) that the scientific-inquiry process, rather than being defined by a set of skills or a set “method” (as “process” or “inquiry” has frequently been defined within science education), is defined primarily by its purpose – which is the development, testing, and revision of scientific models of physical phenomena. In models-based inquiry cycles, students are first exposed to some relevant phenomenon, develop initial models to explain how and why the phenomenon works, determine what evidence or information is needed to confirm or refute aspects of their models, and then go through cycles of gathering this evidence or information,
making meaning of it, and applying it to revise their initial models and more fully and accurately explain the initial phenomenon. In models-based inquiry, teachers generally engage in four core practices in order to support students in this work:

- Planning for engagement with important science ideas
- Eliciting students’ ideas
- Supporting ongoing changes in thinking
- Pressing for evidence-based explanations

(Tools for Ambitious Science Teaching, n.d.)

Both the 5E lesson structure and the more specific models-based inquiry method of instruction serve as a general outline for the design and structuring of learning activities on various scales of time (at the lesson-, multi-lesson-, unit-, and course-level) within this curriculum. In particular, consistent with our sociocultural and constructivist pedagogy, students engage in models-based inquiry cycles as a primary method for constructing the core content knowledge of the curriculum. Additionally, because of its emphasis on defining and mirroring the scientific inquiry process, the models-based method drives student reflection and discussion on the nature of science itself, engaging students in such questions as, “What counts as evidence?”, “What makes a valid test?”, and “What does it mean to explain something?”

While 5E lessons and models-based inquiry cycles are at the core of our curriculum design, we amend these structures in two key ways. First, the discourse generated through the models-based inquiry approach about the nature of science is more critical in nature, asking not only about what “counts” in science but why, and exploring the assumptions, values, and philosophical underpinnings upon which scientific processes of making knowledge rest. Second, because of our emphasis on understanding that is not narrowly limited to explaining and
applying, we amend the types of activities typically found in the various stages of these learning cycles, incorporating opportunities for the development of different forms of “knowledge” and understanding (such as self-knowledge, empathetic or inter-subjective knowledge, and philosophical knowledge) through reflection, sensory and physical engagement, and play. The rest of this learning experience bank describes those core activities which will be embedded in and serve to transmute these inquiry cycles of science knowledge creation.

**Aesthetic Perception:** In aesthetic perception or “phenomenological” activities, students attend directly to their experience with some phenomenon, working to observe it holistically through all of their senses at once, and attempting to avoid filtering this experience through pre-established lenses or conceptual frames, which invariably cut off some of the information otherwise present. According to Dahlin (2001), aesthetic perception is developed through “contemplating something in order to watch its riches unfold” and “involves attentive listening to all the qualities inherent in sense experience (p. 464).” In this curriculum, students develop their aesthetic perception and use it as a method for finding potential meanings in the physical world that extend beyond the merely explanatory or functional. They do this through activities in which they contemplate physical events both familiar and unfamiliar and practice being fully present, looking past their habitual ways of seeing and interpreting, and paying ever closer attention to the totality of their direct sense experience.

**Case-study:** Case-studies are a relatable, engaging, and rich learning resource that provide students with a focused opportunity to analyze real-world phenomena in an in-depth and multilayered way. Through the use of case-studies, phenomena or issues and their surrounding
details and context are unpacked by “explain[ing], describ[ing] and explor[ing]” in order to highlight casual links and derive theories (Crowe et. al, 2011, p. 3). Case-studies allow students to connect to story and draw their own conclusions, through accompanying guided teacher facilitation and follow-up discussion. As Stake (1995) writes, “A case-study is both the process of learning about the case and the product of our learning (p.237)”. In this curriculum specifically, students will use case studies to explore scientifically unexplainable phenomena through medical documentation and/or personal narrative. By doing so, we will be using an instrumental case study which “uses a particular case (some of which may be better than others) to gain a broader appreciation of an issue or phenomenon (Crowe et. al, 2011, p. 2).” Through the use of case studies, the curriculum captures student imagination and curiosity in a way that conceptual informational may not necessarily do.

**Self-Reflection:** Self-reflection creates a space for students to identify thoughts, process information, and draw new understandings. Pool (2018) defines self-reflection as a tool to “promote a deeper sense of openness and receptivity to the often-hidden dimensions of human phenomena while expanding understanding of self and world” (p. 245). Through writing (such as a journal students return to write in throughout the units) or other self-selected medium of choice (video recording), students will develop a dialogue and connection to their innermost worlds - in other words, a ‘wide-awakeness’ (Greene, 1978). Especially since traditional science classrooms do not incorporate time to develop a connection with the self, we intend to prioritize self-reflection as a learning tool, as it will allow students to re-center towards an embodied and spiritual experience of the curriculum.
Guided meditation: Guided meditation is a means of tapping into the interstitial space of the spirit. Teachers will lead students through a meditative or contemplative state through guided prompts and imagery that will allow students to process and imagine scientific concepts in an embodied and spiritual way. An especially salient definition within educational contexts of meditation as a contemplative practice is as a “spiritual exercise” deemed a “spiritual but not religious” practice (Comstock, 2015, p. 33). Carr and Haldane (2003) argue that because students bring an innate sense of curiosity with them into the classroom, it is teachers’ responsibilities to provide the space for this natural sense of wonder to unfold. Miller and Moore (1999) suggest meditation as a way to nurture the inner lives of children, further writing that by acknowledging the soul in the classroom, we can address the big questions in life that continue to evolve with us throughout our lives and create classroom spaces that are truly and wholly engaging for students.

Additionally, guided meditation will be used to create a positive communal space with other classmates in order to foster a sense of shared trust, play, curiosity and respect (more written about this in rationale section). As Ferguson (2005) argues, connecting the ‘cosmos and psyche’ can only be understood in relationship with one another through social experiences, going on to describe the division between the cosmos and psyche is a “relatively recent and peculiarly western division between” the cosmos, as “an external and objective order of the material universe,” and psyche, as “an internal and subjective world of personal experience” (p. 2). Education scholar, Ted Aoki also encouraged teachers to develop the true spiritual nature of their students, especially in relationship with their peers, by injecting spirituality into the curriculum through putting “a premium on the spirit, self, and being, or inner space” (Lee, 2017, p.21). Thus, guided meditation experiences will allow students to gain an embodied, spiritual
and communal experience of science phenomena that is discussed in class, re-orienting them again towards a greater sense of ‘wide-awakeness’ (Greene, 1978).

**Embodied learning / play:** Embodied learning and play attempt to facilitate learning through the functions and movements of the body. As Maxine Greene (1977) states, “aesthetic experience provides a ground for the [kind of] questioning that launches sensemaking and the understanding of what it [means] to exist in a world” (p. 166). It is all the more pertinent to do this for a science curriculum: enriching the way the student experiences the physical world, by engaging in a learning experience *through* it, aligns with our aim of normalizing the subjective sensemaking and understanding of the physical world that is often neglected in science. As such, we draw on some of Hubbard’s (2007) five instances of embodied engagement in order to develop a strategy for creating an embodied learning experience. Three of those instances are of particular relevance: ‘responding with poetry’, ‘becoming the work’ and ‘drawing details’. When ‘responding with poetry’, students are asked to take note of the first word or image that comes to their mind when thinking of an idea or concept, and the resultant words are to be combined to form a poem. When ‘becoming the work’, students gain a more intimate sense of the object they are engaging with as they are asked to collaboratively create it through a coordinated collective arrangement of their bodies. When ‘drawing details’, students get to understand the intricacy and complexity of a certain object or idea through a meticulous engagement with its fine details. Using such learning experiences in an overarching strategy of embodied learning helps students enrich their approach to thinking and learning about science.
## Unit 0 Lesson Plan

### Unit Level Specifics

<table>
<thead>
<tr>
<th>Title of Unit: Introduction and Culture Setting</th>
</tr>
</thead>
</table>

### The specific EU's and EQ's from the unit that lesson aligns to

#### Enduring Questions

- What is the difference between the *unknown* and the *unknowable*? And is anything ultimately unknowable?
- What is the relationship between reality, science, and the self?
- Could there be a single ultimate and verifiable theory to completely describe the universe?

#### Enduring Understandings

- There is legitimate debate and uncertainty regarding why some things about our universe are unknown, and whether they will ever be known.
- When science makes claims about reality, it is based on certain assumptions about reality which are not themselves testable/provable using science.
- Theories that describe the universe do not necessarily need to be complete.

### Core knowledges and skills

#### Content knowledge

1. Unknowability
2. Our reality vs ultimate Reality
3. Subjective Sense of Self
4. Subjectivity and Objectivity
5. Exploration of our relationship with the cosmos and reality/Reality

#### Philosophical Knowledge

1. Contemplating the nature of unknowability, subjectivity vs. objectivity, scientific assumptions of reality
2. Participating in an embodied experience (guided meditation) to engage in understanding of the subjective sense of the self
3. "(Re)claiming our connection to the cosmos by bringing value to subjective ways of experiencing the world through dissolving ideas/assumptions/labels around what constitutes things as legitimately "scientific" (i.e. just because something is not strictly scientific, does not mean it is “unscientific” - perhaps it is simply "non-scientific" or even "more-than-scientific")."

#### Skills

- Critical discussion skills
- Peer-evaluation etiquette
- Obtaining, evaluating, and communicating information
- Perspective-taking
- Self-knowledge, internal awareness, and meta-cognitive reflection
- Engaging in argument from evidence

### NGSS standards - N/A

| Brief statement of Unit Performance Task - N/A |
# Lesson Level Specifics

<table>
<thead>
<tr>
<th>Title of Lesson: The Universe Within and Beyond</th>
<th>Time Spent on this Lesson: 2 days</th>
</tr>
</thead>
</table>

## Lesson objective
This is an introductory lesson that will orient students towards the aims of our curriculum, and primarily highlight the connection between science and creative expression.

### Lesson level question and understanding – what question will students explore and what concept will they attain as a step toward the unit EUs and EQs

- What are some of our own ideas/assumptions/labels around what constitutes things as legitimately “scientific” or not?
- How “scientific” do students believe they are? What factors affect their decision/what makes them think or not think so?
- How creative are we allowed to be when it comes to science?
- By what mechanism do we process reality? How well do our minds process reality?
- What guarantees or ‘checks’ exist for us to verify Reality?

## Keypoints

- The understanding that (objective-appearing) ideas and assumptions around the categorization of what is considered legitimately “scientific” does not have to be true for oneself (or subjectively true)
- Just because an explanation is not strictly "scientific," does not make it "unscientific" - perhaps it is simply non-scientific, or even more-than-scientific
- Subjective ways of experiencing the world are valuable
- Explanation of phenomena are based on our subjective view of reality versus ultimate Reality

## Lesson Context

### Prior
This is the first lesson within the semester long curriculum. Teachers should pay particular attention to modeling an open and trusting community culture.

### Post
Students will continue on to Unit 1 with essential understandings gained in this unit, along with an increased sense of creativity and possibility.

## Assessment / vision of mastery

Several activities in the lesson will serve as primary evidence as to the degree to which students are making progress towards the objectives, understanding, and key points listed above. They include:

### Diagnostic
- Beginning of Day 1: Students complete the pre-assessment activity in their journals. The purpose of this task is to introduce the ways of thinking and forms of engagement
that we intend to develop for students throughout the course of our curriculum. There are no right answers, as the questions are simply meant to stimulate students’ sense of inquiry, curiosity, imagination, and creativity. The questions include: “What does it mean to imagine?” “How is science used in society?” “How is science used by you?” and “What is science to you?”

Teacher wraps up this phase by discussing that we have certain assumptions around what science is, what is real and imaginary, and that the goal of the course is to open to new possibilities of those ideas. Teachers will also record the data from this assessment, via a photo or other method for future use to iterate lessons and gauge students prior knowledge/understandings.

Formative

- **Day 1:** Skit Activity: students will create an alternative ending to the Twilight Zone episode *Parallel Universe*. The purpose of this activity is for students to begin to feel comfortable with creatively imagine new possibilities in the fields of ‘trippy’ science that The Twilight Zone captures so well, as well as to engage with unit philosophical understandings. Students should feel free to move around the room and get excited about the creative nature of this activity.

  *(Skills to look out for - using argument from evidence, critical analyzing information, perspective-taking, self-knowledge, internal awareness, and meta-cognitive reflection)*

- **Day 2:** Teacher will ask students to rank the images based on the level of reality they believe they represent. In small groups, students will take 2-3 minutes to discuss how they made those decisions - what rationale did they use and why?. Then, as a class, students will then share their responses to the following questions: *Are these all pictures of the same thing, or do different pictures represent different realities? What affects how we see these as reality? What makes one rep. more “real” than another? To whom / in what way?*

  *Teachers should look for evidence of critical analysis of information; obtaining, evaluating, and communicating information - to what extent are students able to provide rationale for why they ranked their images in a certain way, and discuss their thoughts and findings with peers.*

Summative

- **Day 2:** Students reflect in their journals - *what’s something they’ve realized over the last few days, and how do you feel about that?* This question is meant to be extremely open for the first lesson. Students can share their journal reflections with the class in a popcorn style.

  *Teacher should model an openness and a willingness to hear students reflections/questions/personal connections etc.*

  *Teacher should look for evidence of skills - critical analyzing information, perspective-taking, self-knowledge, internal awareness, and meta-cognitive reflection.*

<table>
<thead>
<tr>
<th>Classroom set-up</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-circle or circular seating set-up</td>
<td>Student journals</td>
</tr>
</tbody>
</table>
of openness and community

Floor space to perform skits

Comfortable seating options for guided meditation - space for students to choose different positions/areas of the room or different postures

Various digital or hard copy images of space/stars/planets (NASA Hubble telescope images)

Van Gogh’s Starry Night painting and/or other famous images of the cosmos (google images)

5E Lesson Plan

Title of Lesson: The Universe Within and Beyond

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening (5 mins)</td>
<td>Teacher welcomes students to the course.</td>
</tr>
<tr>
<td>Engagement (18 mins)</td>
<td>Students sort cards into two categories: scientific vs. not in small groups. Ex of words used: Creativity, Play, medicine, laboratories. Students will then watch an episode from the Twilight Zone: <em>Parallel Universe.</em> Teachers encourage students to start thinking ‘outside the box’ similarly to the plot twists at the end of each episode. Teacher reflection ques: So how do we know what’s real? What guarantees or ‘checks’ exist for phenomena in the universe? Students complete the pre-assessment activity in their journals. The purpose of this task is to introduce the ways of thinking and forms of engagement that we intend to develop for students throughout the course of our curriculum. There are no right answers, as the questions are simply meant to stimulate students sense of inquiry, curiosity, imagination and creativity. The questions include: “What does it mean to imagine?” “How is science used in society?” “How is science used by you?” and “What is science to you?” Teacher wraps up this phase by discussing that we have certain assumptions around what science is, what is real and imaginary, and that the goal of the course is to open to new possibilities of those assumptions.</td>
</tr>
</tbody>
</table>
### Exploration – students participate in an activity that facilitates conceptual change (35 mins)

Skit Activity: students will create an alternative ending to the Twilight Zone episode *Parallel Universe*. The purpose of this activity is for students to begin to feel comfortable with creatively imagine new possibilities in the fields of ‘trippy’ science that *The Twilight Zone* captures so well, as well as to engage with unit philosophical understandings.

Students should feel free to move around the room and get excited about the creative nature of this activity.

**Teacher guidelines:** norms for students should be established as well as thoughtfulness in creating an environment where mutual respect is valued (before and through this activity).

### Closing (2 mins)

HW Assignment: Teacher will ask students to ‘draw the night sky’ as a homework assignment due the next day/time class meets.

*Teacher intentionally leaves the assignment vague, without providing much or any directions, leaving the assignment as open to interpretation as possible.*

### Day 2

#### Opening (3 mins)

Teacher will lead a guided meditation experience, asking students to explore the following questions:

- Now that you’ve closed your eyes, how do you know that the room you were in is real?
- Try and gain a sense of the room through your 5 senses: how does the room smell? What sounds do you hear?
- Now, try and gain a sense of yourself within the room by *feeling within your body* - guide students to focus their awareness on their feet, then moving upwards through their body. Where does this awareness end?
- How do you know that what it’s in your mind is true?

**Teacher reflection ques:** Teacher asks students to share what they noticed through this experience.

#### Engagement – students’ prior knowledge accessed and interest engaged in the phenomenon

Teacher plays a TEDEd video (~15mins) on the Rubber Hand illusion which demonstrates that our brains actually use our best guess at reality

Viewing these optical illusions will begin to allow students to see
that the relationship between self, reality and the universe lies in our best guess at it.

Teacher reflection ques: So how do we know what’s real? What guarantees or ‘checks’ exist for ourselves?

Teacher asks students to think back to the Twilight Episode. As a class, students will answer: how does the fact these illusions occur right in front of your eyes compare to the ‘checks’ you established yesterday performing the new Twilight Zone episode?

**Explanation** – students generate an explanation of the phenomenon

Students take out their creative expression of drawing the night sky from the previous night.
The teacher poses the question: *Is the way you see the universe the same way others see the universe?*

In an elbow-pair share students share their images and discuss their thoughts on the questions above - what did they capture and why?, what emotions did this activity elicit?

**Elaboration** – students’ understanding of the phenomenon challenged and deepened through new experiences

As extension of the activity above, students will compare their drawings of night sky to a) other famous artistic representations of night sky (e.g. Van Gogh Starry Night, as well as more "literal" artistic representations); and b) "scientific representations" (picture taken from telescope/outer space, representation of galaxies on a map of the sky, etc.).

Teacher will ask students to rank the images based the level of reality they believe they represent. In small groups, students will take 2-3 minutes to discuss how they made those decisions - what rationale did they use and why?.

As a class, students will then share their responses to the following questions:

*Are these all pictures of the same thing, or do different pictures represent different realities? What affects how we see these as reality? What makes one rep. more "real" than another? To whom / in what way?*

To close, the teacher poses the question: So how do we know what’s real? What guarantees or ‘checks’ exist within the ‘science’ field?

Through these comparisons students begin to see the connection between science and subjectivity, reality and Reality - highlighting that current explanations of scientific phenomena varies based on
our personal assumptions and subjective experience of reality, not Reality.

<table>
<thead>
<tr>
<th>Evaluation – students assess their understanding of the phenomenon (5 mins)</th>
<th>Students return to their journals to reflect on something they’ve realized over the last few days, and how do you feel about that?</th>
</tr>
</thead>
</table>
| Closing (5 mins) | Students can share their journal reflections with the class in a popcorn style.  

*Teacher should model an openness and a willingness to hear students reflections/questions/personal connections etc.* |
## Unit 1 Lesson Plan

### Unit Level Specifics

<table>
<thead>
<tr>
<th>Title of Unit:</th>
<th>What else is out there?: Dark Energy and Dark Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUs and EQs from the unit that the lesson aligns to:</td>
<td>Core Knowledge and Skills from unit that lesson aligns to:</td>
</tr>
<tr>
<td>Essential Question:</td>
<td>Content Knowledge:</td>
</tr>
<tr>
<td>Will we ever know everything that is in the universe?</td>
<td>1. Doppler effect: redshift and blueshift as evidence of light’s motion</td>
</tr>
<tr>
<td>What does it mean to be invisible?</td>
<td>2. Relationship between mass of a star and light generated (as means of determining amount of mass in a galaxy)</td>
</tr>
<tr>
<td>Enduring Understandings:</td>
<td>3. Big Bang theory - history of, evidence for, major claims of...</td>
</tr>
<tr>
<td>For something to be known to exist (by us), it must be in interaction with something else. We can only know the existence of something through its interaction with something else.</td>
<td>Philosophical Knowledge:</td>
</tr>
<tr>
<td></td>
<td>1. Relationship between mathematics and science - history of how quantifiability became central to scientific explanations, how “making the equations work” is still central to how/why scientists propose or reject new theories, including proposing existence of “stuff” that there is otherwise no evidence for</td>
</tr>
<tr>
<td></td>
<td>Skill:</td>
</tr>
<tr>
<td></td>
<td>1. Asking questions</td>
</tr>
<tr>
<td></td>
<td>2. Engaging in argument from evidence</td>
</tr>
<tr>
<td></td>
<td>3. Developing and using models</td>
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<td></td>
<td>4. Perspective-taking</td>
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<tr>
<td></td>
<td>5. Guided imagination / Empathy</td>
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<td></td>
<td>6. Counterfactual thinking</td>
</tr>
<tr>
<td></td>
<td>7. Self-knowledge, internal awareness, and meta-cognitive reflection</td>
</tr>
</tbody>
</table>

### NGSS

**HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

### Connection to Unit Performance Task

At the end of the unit, students will create a living timeline of the discovery of dark matter and dark energy that should capture the ideas and theories that lead to their discovery. This lesson will cover some of the concepts that lead to this discovery. By understanding how the movement and gravitational equilibrium observed by several different phenomena point to the existence of masses and energies that have
not been accounted for by scientists, this lesson makes the path to the discovery become clearer for the unit performance task.

**Lesson Level Specifics**

<table>
<thead>
<tr>
<th><strong>Title of Lesson:</strong> Mass, light and the discovery of dark matter/energy</th>
<th><strong>Time Spent on this Lesson:</strong> 1 days</th>
</tr>
</thead>
</table>

**Lesson objective: Learners will be able to...**

- explain the doppler effect: how the blueshift and redshift of observed light from stars indicates that they are accelerating or decelerating but ultimately moving away from each other – evidence that the universe is expanding.
- explain how the doppler effect, in conjunction with kepler’s third law, determines the mass of stars.
- analyze how the relationship between the mass and acceleration of known objects in the universe reveals that there exists a form of energy and mass that make up 95% of the mass-energy of the ‘observable’ universe.
- interpret the discovery of dark matter and dark energy through the lens of knowability – what does the nature of this discovery reveal about reality and science’s ability to observe reality?

**Lesson level question and understanding - what question will students explore and what concept will they attain as a step toward the unit EUs and EQs?**

**Lesson Question:** How did scientists discover dark matter?

**Lesson Understanding:** Waves contract and expand according to how they are moving relative to the observer. Scientists used this fact in relation to several other advanced physics and mathematics theories to determine that planets and galaxies are moving further and further away from each other, revealing that the universe is expanding. The speed at which it is expanding reveals that there is an energy source that is unaccounted for. Further, the speed at which stars orbit their corresponding galaxies reveals that there is a certain unaccounted for mass that exists in those galaxies. The specific calculations have revealed that ~95% of the mass-energy of the universe is actually unaccounted for. Scientists have called it dark matter and dark energy because it can not be detected using light, but nothing else is known.

**Key points:**

- There is constant speculation on what dark matter and dark energy could be because of the near impossibility of directly observing it.
- The Doppler Effect reveals how waves compress or expand according to their relative speed to the receiver.
- Scientists used the doppler effect in conjunction with some advanced astrophysics and mathematics to calculate how fast planets are moving, and how fast stars are orbiting.
their galaxies.
- Having found that speed, and observing that galaxies are moving away from each other faster than the total observed energy of the universe suggests, in addition to observing that stars are orbiting their galaxies faster than the total matter of the universe can allow (according to the theories of relativity), the accounted for mass-energy has been calculated to be 5%, with the remaining 95% of the mass-energy of the universe speculated to be made up of a form of matter and energy that light can not detect.

**Lesson Context**

<table>
<thead>
<tr>
<th>Prior: Students will have undergone a few preliminary activities and lessons to get them used to the ideas of the unknown, unknowability, mass, gravity and speed.</th>
<th>Post: This lesson will reveal how dark matter and dark energy are thought to exist not through any direct observation, but through lateral ones that alluded to their existence. This sets the stage for further inquiry into the nature of knowability in science: if 95% of the mass-energy of the universe is speculated to be composed of something that contemporary science can only indirectly 'observe', what does that say about the nature of reality and science’s ability to observe reality?</th>
</tr>
</thead>
</table>

**Assessment / vision of mastery**
Several activities in the lesson will serve as primary evidence as to the degree to which students are making progress towards the objectives, understanding, and key points listed above. They include:

**Diagnostic**
- Beginning of Day 1: “Finding your way in the dark activity” where light is turned off and students are asked to navigate their way around the classroom without being able to see. Upon completing the activity, students are asked: “How did you find your way around classroom if you can not see?” *Teacher uses this information to gauge how students think about indirect observation, where other pieces of information about something is used in order to indirectly observe it. This activity should last no longer than 10 minutes.*

**Formative**
- Day 1: Students will view the following video [https://www.youtube.com/watch?v=p-hBCcmCUPg](https://www.youtube.com/watch?v=p-hBCcmCUPg) and join in groups for around 3-5 minutes to discuss what they think about what they saw. They should be able to explain it however they want, but encouraging them to present their thinking through drawing is a plus. *If the teacher would like that to be the way this activity is done, or if it has been mutually decided/negotiated to try drawing, the teacher should look for instances where a curved line representing the change in sound is drawn. The teacher should also give some guiding questions to insinuate that the change in sound may not only be a ‘loudness’ issue if the teacher sees that there is where most students are taking it.*

**Summative**
- Spend some time speculating, again in groups, on what dark matter could be. The
students will simply need to imagine anything that they believe could be a hidden force that is moving the cosmos. These could include emotions, thoughts, feelings… your lost socks. Inspire them by asking, “What would you like to think is out there in the unexplored phenomena of the universe?”

<table>
<thead>
<tr>
<th>Classroom set-up</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group seating layout.</td>
<td></td>
</tr>
</tbody>
</table>

Day 1

<table>
<thead>
<tr>
<th>Phase</th>
<th>5E Lesson Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement / Opening</td>
<td>“Finding your way in the dark activity” where light is turned off and students are asked to navigate their way around the classroom without being able to see. Upon completing the activity, students are asked: “How did you find your way around classroom if you could not use your eyes to see and observe your surroundings?” (7-10 min.)</td>
</tr>
<tr>
<td>Exploration (1)</td>
<td>Students will view the following video <a href="https://www.youtube.com/watch?v=p-hBCcmCUPg">https://www.youtube.com/watch?v=p-hBCcmCUPg</a> and join in groups for around 5-7 minutes to discuss what they think about what they saw. They should be able to explain it however they want, but encouraging them to present their thinking through drawing is a plus. If the teacher would like that to be the way this activity is done, or if it has been mutually decided/negotiated to try drawing as the activity to represent the phenomenon seen in the video, the teacher should look for instances where a curved line representing the change in sound is drawn. The teacher should also give some guiding questions to insinuate that the change in sound may not only be a ‘loudness’ issue if the teacher sees that there is where most students are taking it. (10 min.)</td>
</tr>
</tbody>
</table>
| Explanation (1)        | Each group presents what they found for a minute or two maximum. The teacher must then use what the students brought to the discussion and reframe it as what is called (emphasizing a statement like this aligns with some of the goals of this curriculum in removing the authority science has on describing reality) the Doppler Effect. Give them the following prompt to read and take notes on individually: “The video revealed how sound waves expand and contract to change the pitch of the sound according to the speed and position of the car
relative to the observer. The Doppler effect applies to light as well, however, where the *pitch* of the light is indicated by its *color*. The doppler effect occurs through light only if the object is moving at speeds close to the speed of light. Telescopes use this effect to determine how stars and galaxies are moving, and at what speeds, through observing the change in their color. The spooky thing about this is: planets and galaxies move according to gravity, which relativity (more on that in later units) shows is related to mass and energy. The stars and galaxies, however, are accelerating at speeds that relativity determined as too fast for the accounted for mass and energy of the universe! So much so that the unaccounted for mass-energy of the universe is found to be 95% !!! This unaccounted mass-energy is called Dark Matter and Dark Energy, with Dark Matter composing around ~25% of it and Dark Energy composing the remaining ~70%”

These facts are difficult for high school students to explore individually or through scaffolded activities. Providing a prompt and having them read it individually (then discussing it in a group) is therefore a good alternative. It also develops the skill of reading and analyzing scientific texts in addition to encouraging that they be discussed with peers.

<table>
<thead>
<tr>
<th>Elaboration (1) – students’ understanding of the phenomenon challenged and deepened through new experiences (13 mins)</th>
<th>The students will now spend some time with this prompt in groups to first analyze it further in order to understand it better, in addition to how it relates to their analysis of the car horn video, and then engage in a collective speculation on what dark matter or energy could be. The students will simply need to imagine anything that they believe could be a hidden force that is moving the cosmos. Inspire them by suggesting that their imagination can include ideas as far fetched as emotions, thoughts, feelings… their lost socks. Inspire them by asking, “What would you like to think is out there in the unexplored happenings of the universe?”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closing (3 min.)</td>
<td>Ask them to watch/rewatch <em>Interstellar</em> using some of the insights they gained from this session. (The main idea of the movie is the fact that emotions and feelings are the forces that move and shape gravity, and which end up solving the mysteries of the universe to save earth)</td>
</tr>
</tbody>
</table>
## Unit 2 Lesson Plan

### Unit Level Specifics

<table>
<thead>
<tr>
<th>Essential Question:</th>
<th>Content Knowledge:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a difference between measuring and observing? What does the existence or non-existence of this difference say about how we think of reality?</td>
<td>1. Observations and experiments done on atomic and subatomic particles showed that the forces of electromagnetism, strong nuclear force and weak nuclear force are governed by a completely different type of physical phenomenon, which quantum physics is a valid model for describing.</td>
</tr>
<tr>
<td>Enduring Understandings:</td>
<td>2. Quantum physics introduces the idea that, on a small enough scale, an object’s physical properties are probabilistically determined.</td>
</tr>
<tr>
<td>There is an ambivalence on whether or not there can be an ultimate theory for describing the universe.</td>
<td>a. Double-slit experiment shows how light can be understood as both a wave and a particle. Using electrons in this experiment without knowing which slit they pass through produces the same pattern that light shone on a slit produces.</td>
</tr>
<tr>
<td>Framing your investigation of reality affects the theories on reality that we end up developing</td>
<td>Quantum based on the fact that the physical properties of objects at the atomic/subatomic scale are not continuous, but exist in discrete states.</td>
</tr>
</tbody>
</table>

### Core Knowledge and Skills from unit that lesson aligns to:

**Content Knowledge:**

1. Observations and experiments done on atomic and subatomic particles showed that the forces of electromagnetism, strong nuclear force and weak nuclear force are governed by a completely different type of physical phenomenon, which quantum physics is a valid model for describing.
2. Quantum physics introduces the idea that, on a small enough scale, an object’s physical properties are probabilistically determined.
   a. Double-slit experiment shows how light can be understood as both a wave and a particle. Using electrons in this experiment without knowing which slit they pass through produces the same pattern that light shone on a slit produces. Quantum based on the fact that the physical properties of objects at the atomic/subatomic scale are not continuous, but exist in discrete states.

**Philosophical Knowledge:**

1. Since scientists are completely baffled by how to reconcile the two theories, and in the spirit of science as a space for imaginative yet scientifically grounded inquiry, creativity and imagination is an acceptable attempt to reconcile them.
2. Unit relies heavily on phrases such as “Can be understood”, “is said to be”, “are thought to exist”, etc. to reaffirm that these theories are simply models to understand how things work. They are not representative of some truth or reality about the nature of the physical universe.

**Skill:**

1. Asking questions
2. Engaging in argument from evidence
3. Developing and using models
4. Perspective-taking
### NGSS

**HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.**

### Connection to Unit Performance Task

At the end of the unit, students will take the role of a knowledgeable scientist who is speaking to a scientifically literate audience. Having the option to present in several different formats, including a written proposal, poster, or an oral conference presentation, the task asks that students consider the theories of quantum physics and relativity, showing the tension/incompatibility between them, then possibly reconciling the two, or maybe even rejecting them, in imagining a new theory.

### Lesson Level Specifics

#### Title of Lesson: The double-slit experiment: particles or waves?

#### Time Spent on this Lesson: 2 days

**Lesson objective: Learners will be able to...**

- describe how the double-slit experiment reveals that light and matter carry characteristics of both waves and particles.
- deduce how the framing of an observation or experiment influences the nature of its conclusions.

**Lesson level question and understanding - what question will students explore and what concept will they attain as a step toward the unit EUs and EQs?**

Lesson Question: In what ways do the insights on observability provided by the double-slit experiment force us to rethink the nature of matter in the universe?

Lesson Understanding: The double-slit experiment not only reveals the wave-particle duality of matter, but also shows how the act of observation in itself affects the conclusions of the experiment. If light or a stream of particles pass through two slits without the observer knowing which ones they pass through, the resultant pattern appears to follow the behavior of two waves interfering. If the same light or stream of particles are tracked in order to know which slit they passed through, however, the resultant pattern appears to follow the behavior of a single wave and there is no interference pattern. The act of observation collapses the behavior of particles as if they passed through a single slit – what does this say about the role of observation in making claims about reality? Can observations give us any true sense of the nature of reality?
Key points:

- The double-slit experiment involves a beam of light or particles that are shot at a barrier which contains two slits. The pattern created after they pass through the slits is detected on a screen or detector that is placed at a reasonable distance away.
- Diffraction occurs when a wave passes through a slit and propagates circularly outwards, like a water current does after being funneled out of a small opening. Having two slits causes an interference pattern to occur.
- On a small enough scale, light also diffracts after when pointed at two very narrowly separated slits, exhibiting wave-like behavior.
- When detected on the detector/screen, however, it does not appear to be a continuous and smooth wave, but rather an amalgamation of particles that collectively follow the pattern of a wave; the light particles–photons–are behaving like waves. This is called the wave-particle duality.
- Further, if extremely tiny particles, such as electrons, are shot one by one at the two slits (again, with no knowledge of which slit they pass through), the resultant pattern also exhibits a wave like pattern. This means that on small enough scales, the movement of individual particles is probabilistically determined.
- If we trace which slit each electron passes through, the resultant pattern follows the pattern of single slit diffraction – the act of observation changes the movement of the electrons!

Lesson Context

**Prior:** Students have been introduced to the concepts of relativity and, less comprehensively, quantum physics. They will know that there is a tension between the two theories, and this lesson will introduce the aspects of quantum physics that lead to the incompatibility between it and relativity.

**Post:** This lesson is an introductory lesson to the theories of quantum physics, and is thus to be followed by further lessons on the subject. It adds to the discussion on the conflict between relativity and quantum by revealing a the fundamentally different type of physics that govern physical objects on a small enough scale.

Assessment / vision of mastery

Several activities in the lesson will serve as primary evidence as to the degree to which students are making progress towards the objectives, understanding, and key points listed above. They include:

**Diagnostic**

- Beginning of Day 1: The class will rearrange the classroom seating layout into a group layout. They have done so in the beginning of the semester as well for their pre-assessment task, but they are asked to do so again as a reminder that this lesson will also involve some rethinking about their conceptions of light and matter. Each group will then examine an image chosen from a set of three that involves light diffraction which they will need to interpret in their own way. *The teacher will use the students’ interpretations*
of the images to gauge what they are currently thinking and refer back to it when

Formative

- Day 1: Students will be given the opportunity to play with the simulation of wave interference provided in this website: [https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html](https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html). Choosing the “slits” option upon entering the website, they will be given a period of 5-10 mins to experiment with the corresponding simulation and different manipulatives given. *Teacher should make sure that students choose ‘light generator’ and click on the ‘screen’ and ‘intensity’ checkmarks.* The class comes back as a whole and each group presents what they learned about wave interference. *Teacher should make sure that students talk about the intensity pattern, and interrogate how it relates to interference and what is seen on the screen.*

- Day 2: Group activity – Each group will have one member get up and face a certain direction with a (harmless) object in hand. The other members must close their eyes, thinking about where they expect the object to land meanwhile, and the teacher should ask the thrower to throw the object in any direction they choose but remain facing forward. *Teacher needs to be careful that no one gets reckless.* Members should now open their eyes and first discuss where they expected to ball to land and where it actually landed. Repeat this activity several times, asking the group to take note of their expectations versus their observations each time. *Teachers should walk around and check on these discussions to see if there was an agreement/disagreement about where group members expected the object to be thrown and where it was actually thrown, in addition to any notes on words/phrases such as ‘probability’ or ‘I expected it to’ or ‘it will probably land’.*

Summative

- Day 2: Imagining what happens to the stream of particles that are shot through the slits during the period where we do not know which slit they passed through and how they are moving through space. Creativity is encouraged but to be loosely bound by the concepts of the lesson. *Teacher should look for evidence of imagination/empathy and self-knowledge/internal awareness - to what extent are students able to project themselves into a strange scenario and speculate generatively and meaningfully about their possible responses, and to what extent are students able to see their own assumptions as revealed in their earlier work - as well as changes in their philosophical/content knowledge.*

<table>
<thead>
<tr>
<th>Classroom set-up</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First day</strong></td>
<td>• Devices (computers/laptops)</td>
</tr>
<tr>
<td></td>
<td>• Set of images (detailed below)</td>
</tr>
<tr>
<td></td>
<td>• Worksheet (outline given below)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5E Lesson Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
</tr>
<tr>
<td><strong>Phase</strong></td>
</tr>
<tr>
<td><strong>Engagement / Opening</strong></td>
</tr>
</tbody>
</table>
**Exploration (1)** – students participate in an activity that facilitates conceptual change (17 min.)

- Students will play with the simulation of wave interference and light diffraction that is provided in this website: [https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html](https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html).

- They will be given a worksheet that details the instructions of this experiment:
  
  Choose the “slits” option upon entering the website. Choose the ‘light generator’ simulation option (come ask me for help if you can’t find where that is). Click on the ‘screen’ and ‘intensity’ checkmarks. Choose ‘two slits’ from the drop down menu. Now click on the green button on the left.
  
  (Insert *Simulation Settings Image* in the worksheet, available at Annotated Resources and Materials page)

  You have a period of 10-15 mins to experiment with the corresponding simulation and different manipulatives given, and fill out the following table:

<table>
<thead>
<tr>
<th>Question</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is happening to the light as it passes through the slit?</td>
<td></td>
</tr>
<tr>
<td>What is happening to the light in the area between the slits and the screen?</td>
<td></td>
</tr>
<tr>
<td>Describe the resultant pattern you see on the screen.</td>
<td></td>
</tr>
<tr>
<td>How do you think this pattern formed? How is it related to what you ‘theorized’ in the second question?</td>
<td></td>
</tr>
</tbody>
</table>

**Explanation (1)** – students generate an explanation of the

- The class comes back as a whole and each group presents what they learned about the simulation. *Teacher should make sure that students discuss the intensity pattern on the screen in relation to their interpretation of the wave interference phenomenon occurring between the screen and the slit.*
<table>
<thead>
<tr>
<th><strong>Day 2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase</strong></td>
</tr>
<tr>
<td><strong>Opening</strong> (5 min.)</td>
</tr>
<tr>
<td><strong>Exploration (2) – students participate in an activity that facilitates conceptual change</strong> (13 min.)</td>
</tr>
</tbody>
</table>
and check on these discussions to see if there was an agreement/disagreement about where group members expected the object to be thrown and where it was actually thrown, in addition to any notes on words/phrases such as ‘probability’ or ‘I expected it to’ or ‘it will probably land’.

<table>
<thead>
<tr>
<th>Explanation (2) – students generate an explanation of the phenomenon (15-20 min.)</th>
</tr>
</thead>
</table>
| The class comes back together and a discussion begins around several guiding questions: how did members of a group predict where the object will land? Did this prediction align with where the ball actually landed?  

After the discussion, which should last around 5 minutes, the teacher relates it back to the double slit experiment, where something similar has been done by scientists.  

Scientists fired a single electron through a double slit screen, without knowing which slit it passed through, and found the following results upon firing thousands more, one at a time:  
[https://www.youtube.com/watch?v=ZqS8Jjk1HI](https://www.youtube.com/watch?v=ZqS8Jjk1HI)

The following video should then be shown, which deals with the rather heavy concepts illuminated by this experiment in a simple, fun and quirky way:  
[https://www.youtube.com/watch?v=UMqtIF_XIQQ](https://www.youtube.com/watch?v=UMqtIF_XIQQ)

It will be difficult for students to grapple with what the video is discussing, so part of this activity must involve them watching the video together as a group then taking notes on how its ideas have developed and making sure that they outline its concepts in the best way they can. This develops an essential skill in science: collaboration when developing ideas.

The teacher’s assessment of this activity can be done by simply walking around and seeing how students are talking about and developing their ideas and concepts about the phenomenon. They are simply synthesizing ideas here, albeit pretty complex ideas, so this does not require a large class discussion as students will probably come with the same answers.

The description below is the curriculum designers’ own interpretation of the phenomenon presented in the first video, simplified to be grasped for high school students. The teacher can use this information to guide how the students have developed their explanation of what happened in the video:

** A density pattern has formed on the screen! This density pattern, furthermore, is the same as the pattern that has been
discovered in the previous class session as a result of wave interference! It is as if a single electron had this innate probability that determines where it lands based on a wave-like interference with something that occurs on its way to the screen.

Scientists do not really know what that something is, but one of the theories they came up with is that it is another state of the same electron. The electron can be in two states in this situation: one occurs if it passed through the first slit, the other if it passed through the second slit. The two states then interfere with each other probabilistically, where the probability is determined according to the regular wave interference pattern we observed in the previous session. As such, the electron has a wave-particle duality. Even spookier, if there is a detector that sees which slit the particle passes through, this very act of detecting makes the particle behave as if it is a particle, simply passing straight through with no interference pattern occurring on the screen. The electron can not be observed as both a wave and particle at the same time, even though, depending on how the experiment is conducted, they show elements of both.

Nonetheless, this result still baffles scientists because it is hard to think of one object as existing in two separate states that interact with each other, which implies that the object has two versions of itself interacting with each other before observation… this is, truly, a baffling concept. More, it is even harder to think about how the experiment itself can determine the nature of the object in question (whether it is a particle or wave in the case of the electron).**

Elaboration/Evaluation (2)
- students’ understanding of the phenomenon challenged and deepened through new experiences
- students assess their understanding of the phenomenon (12-17 mins)

After the preceding activity is done, students remain in groups to come up with their own ideas of what they think happens to the electron from the moment it passes through the slits up until it hits the screen. They should be encouraged to think however they want and be as imaginative as they can about what really happens to the electron, not bound by what the video claims, as scientists at this point are themselves not really sure either. The class at this point should have around 15-20 more minutes left, so each group should spend around 10-12 minutes compiling all the possibilities that group members can think of, then the entire class comes together for a large class discussion, where the lesson closes off with each group sharing their ideas of what dark matter and dark energy could be, and inquiring about what other groups have developed. This should be left as an open and flexible activity so students can wonder and inquire freely about what truly happens to an electron in the double slit experiment.
## Unit 3 Lesson Plan

### Unit Level Specifics

<table>
<thead>
<tr>
<th>Title of Unit: <strong>Who’s really in control?: Determinism and the Brain</strong></th>
</tr>
</thead>
</table>

### The specific EUs and EQs from the unit that that lesson aligns to:

<table>
<thead>
<tr>
<th>Essential Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>By what mechanisms do humans heal?</td>
</tr>
<tr>
<td>Can healing be explained solely through biology?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enduring Understandings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumptions around the depth of our free will determines current Western medical practices.</td>
</tr>
</tbody>
</table>

### Core knowledge and skills:

#### Content knowledge

1. Free will
2. Determinism
3. Human Anatomy
4. Brain Anatomy
5. Complementary and Alternative Medicines
6. Placebo Effect
7. Healing

#### Philosophical Knowledge

1. Contemplating the mind-body connection through embodied experience (guided meditation), case studies, and an fishbowl activity

#### Skills

- Critical discussion skills
- Peer-evaluation etiquette
- Giving and receiving feedback
- Critical analyzing information
- Obtaining, evaluating, and communicating information
- Perspective-taking
- Self-knowledge, internal awareness, and meta-cognitive reflection
- Engaging in argument from evidence

### NGSS standards

<table>
<thead>
<tr>
<th>MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-LS1-3. Use argument supported by evidence for how the body is a system</td>
</tr>
</tbody>
</table>

### Brief statement of Unit Performance Task

**Free Write & Skit:**

Students will contemplate the following question:

*Do we or don’t we have free will?*

Next, they pick the opposite opinion to their original answer! Then, they will free-write and creatively perform (if comfortable) their response around the question: *What would be different about your life or experiences if this were true?*
of interacting subsystems composed of groups of cells.

<table>
<thead>
<tr>
<th>Lesson Level Specifics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title of Lesson:</strong> The Mind-Body Connection</td>
</tr>
<tr>
<td><strong>Time Spent on this Lesson:</strong> 3 days</td>
</tr>
</tbody>
</table>

**Lesson objective: Learners will be able to…**
- Become familiar with the placebo effect and other complementary and alternative medicines
- Understand by what mechanism the placebo effect occurs
- Contemplate the pros/cons of using placebos as a medical strategy for healing
- Relate ideas (both objective and subjective) about the mind-body connection and free will to the potential mechanisms of healing

**Lesson level question and understanding - what question will students explore and what concept will they attain as a step toward the unit EUs and EQs?**

Lesson Questions: What are some alternative and complementary healing pathways humans have practiced and the medical community used, and on what assumptions regarding free will, brain science and the mind-body connection do they rest?

Lesson Understanding: Theories regarding the role of the mind-body connection and free will and the physical capacities of the human brain and body in healing are not medically agreed upon, as healing outcomes have been proven to differ from person to person via our subjective relationship to the beliefs around these various capacities/connections. Thus our subjective beliefs around the mind-body connection, free will and the physical capacities of the human brain and body, directly influences an individual's relationship to healing.

**Keypoints**
- The belief that free will plays a role in complementary and alternative medicines
- Engagement appears to enhance the placebo effect
- The idea that healing taps into the mind-body connection in ways that Western medicine does not fully understand

**Lesson Context**

<table>
<thead>
<tr>
<th>Prior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will have learned about human brain anatomy and the mechanisms under which normal homeostasis occurs in the previous lesson. A class driving question board that has been created in the beginning of the Determinism and the Brain Unit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will continue on to the last lesson in the Human Determinism and the Brain Unit.</td>
</tr>
</tbody>
</table>
(around free will and the phenomena human biology/brain science cannot explain) will be hung in the classroom, listing guiding questions for the unit.

Shamanism will be explored as another complementary and alternative path towards healing.

Assessment / vision of mastery

Several activities in the lesson will serve as primary evidence as to the degree to which students are making progress towards the objectives, understanding, and key points listed above. They include:

Diagnostic
- Beginning of Day 1: Students will begin by individually reflecting in their journals on the following question: "Do you think you can heal yourself through your thoughts? Why / why not?"
- As a group students will complete a KWL chart on the placebo effect before and then after watching a clip on the placebo effect. 
  Teacher should assess students’ prior knowledge and assumptions around the placebo effect, free will, brain science, healing, the mind-body connection.

Formative
- Day 1: ‘7-minute write’ on TEDEd forum - Students contribute their insights to the guided discussion on the TedED forum around the question: Do you think the placebo effect is real or imagined? What makes you believe so? This is a generative assignment meant to elicit students thinking from the day.
  (Skills to look out for - using argument from evidence, critical analyzing information, perspective-taking, self-knowledge, internal awareness, and meta-cognitive reflection)
- Day 2: Case-Study Activity: In small jigsaw groups, students will form expert groups and read/watch/listen to one piece of evidence from the below list (ex’s include personal narratives or medical experiments around complementary and alternative medicines) which highlight the mind-body connection.
  Teachers should look for evidence of critical analysis of information; obtaining, evaluating, and communicating information - to what extent are students able to dissect their case studies, ask pointed questions, and discuss their thoughts and findings with peers.
- Day 3: Fishbowl: Students will engage in a fishbowl discussion about the role of expectation, belief, and the biological mechanisms by which patients were/were not able to alleviate pain and/or heal from illness. Teachers will prompt students to use content knowledge around the human body systems, studies on free will, consciousness, and the medical nature of healing in their discussions.
  Teachers should look for evidence of making arguments from evidence and critical discussion skills, as well as communicating information - to what extent can students communicate what they learned in their case studies and draw connections to prior content knowledge and philosophical understandings with their peers.
Fishbowl Peer to Peer Feedback: Students will have the opportunity to give and receive feedback to their peers on their critical discussion skills that took place in the fishbowl. 

*Teachers will look for evidence of students giving and receiving thoughtful feedback, and practicing their peer-evaluation etiquette.*

**Summative**

- **Day 3**: Students reflect on where they currently stand on the original question posed at the beginning of the lesson: "*Do you think you can heal yourself through your thoughts? Why / why not?*" Have their opinions changed over the last few days? If so, in what ways?

  *Teacher should look for evidence of both content and philosophical knowledge gained throughout the lessons with particular emphasis on findings from the fishbowl activity - to what extent are students able to build perspectives from various case studies discussed, as well as thoughtfully draw connections from ideas illuminated by their peers in the fishbowl activity. Skills to check for - using argument from evidence, critical analyzing information, perspective-taking, self-knowledge, internal awareness, and meta-cognitive reflection.*

**Classroom set-up**

- Small groups
- Fishbowl set-up (half class in the center/remaining half surrounding)
- Ability to dim lights for guided meditation session

**Materials**

- Individual technology for students to contribute to 
- TedED prompt
- Chart Paper
- Student Journals

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**5E Lesson Plan**

**Title of Lesson:** The Mind-Body Connection

<table>
<thead>
<tr>
<th>Phase</th>
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<tbody>
<tr>
<td><strong>Engagement</strong></td>
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<td>prior knowledge</td>
<td>Students will begin by individually reflecting in their journals on</td>
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<td><em>through your thoughts? Why / why not?</em>&quot;</td>
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<td>engaged in the</td>
<td>As a group we will complete a KWL chart on the placebo effect.</td>
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<td>phenomenon</td>
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<td><strong>Exploration</strong></td>
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<td>students</td>
<td>Students will engage in a guided meditation exercise that asks</td>
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<td>an activity</td>
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<td>that facilitates</td>
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deep relaxation in the body (3 mins). Teacher will debrief what and how they felt, and pose the question: *where in the body did those feelings emerge from? By what mechanism did you employ to generate those feelings?* These questions will draw from students prior knowledge from lessons on free will.

Students watch a ~8 minute clip of the film *Placebo: Cracking the code* that provide an overview of the placebo effect, its history in the medical field, and highlight the fact that in many medical communities particularly in the West, practitioners do not believe in its validity and/or are ethically weary of using the placebo effect with patients.

Debrief on the information contained in the film as a class by returning to the KWL chart to fill in additional information.

**Engagement 2**—students’ prior knowledge accessed and interest engaged in the phenomenon

(7 minutes)

‘7-minute write’ on TEDEd forum

Students contribute their insights to the guided discussion on the TedED forum around the question: *Do you think the placebo effect is real or imagined? What makes you believe so?*

**Day 2**

**Exploration 2**—students participate in an activity that facilitates conceptual change

(35 mins)

Case-Study Activity: In small jigsaw groups, students will form expert groups and read/watch/listen to one piece of evidence from the below list (ex’s include personal narratives or medical experiments around complementary and alternative medicines) which highlight the mind-body connection.

Case-Studies:
1. *The Island Where People Forget to Die* - remarkable case of a man living beyond his short cancer prognosis by moving back to Greek hometown (NY Times article)
2. *Yoga and Veterans: A Different Kind of Warrior* (NY Times Article)
3. *Meditation’s Effects on the Mind & Body* (NY Times Article)
4. *What if the Placebo Effect Isn’t a Trick?* (NY Times Article)

**Explanation**—students generate an explanation of the phenomenon

(15 mins)

Students re-group and share their findings with students around their piece of evidence. Students who are listening will become reporters - jotting down evidence they find illuminating and useful to bring into the fishbowl activity.
### Elaboration – students’ understanding of the phenomenon challenged and deepened through new experiences

(45 mins)

Fishbowl: Students will engage in a fishbowl discussion about the role of expectation, belief, and the biological mechanisms by which patients were/were not able to alleviate pain and/or heal from illness. Teachers will prompt students to use content knowledge around the human body systems, studies on free will, consciousness, and the medical nature of healing in their discussions.

Teacher can use the below starter question or use one a student poses, or one that emerges organically during instruction.  
*Starter Question: By what mechanism do humans heal?*

(30 mins)

The remaining half of students will be Talk Detectives, noting students using critical discussion skills, and using argument from evidence using a checklist provided. Afterwards, students will have the opportunity to give and receive feedback to their peers, practicing their peer-evaluation etiquette. Teacher will make sure to set norms before this activity begins.

(15 mins)

### Evaluation – students assess their understanding of the phenomenon

(7 mins)

Students reflect on where they currently stand on the original question posed at the beginning of the lesson: *"Do you think you can heal yourself through your thoughts? Why / why not?"* Have their opinions changed over the last few days? If so, in what ways?

Teachers will prompt students to use both content and philosophical knowledge gained throughout the lessons and particular evidence from the fishbowl activity.

### Additional Notes on Accessibility:

- Sentence starters can be located on the board to help students to generate ideas for their ‘7 minute’ write on the TedED forum.
- Some students may keep an audio or video journal, rather than a written one (ie. these students may record their reflections rather than write them down.)
• If students do not feel comfortable closing their eyes or participating in the guided meditation exercise, ask students to participate in whatever way feels comfortable for them. They can perhaps return to their journal and/or just silently sit with the group.

• In addition or supplement to informational readings, alternative representations of the same information can be offered. This may include short videos or audio recordings, podcasts etc.
# Unit 4 Lesson Plan

## Unit Level Specifics

<table>
<thead>
<tr>
<th>Title of Unit: “Am I a Robot?” The Science of Consciousness</th>
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</table>

### EUs and EQs from the unit that the lesson aligns to:

- **Essential Question:** How do I know that you’re not a robot? How do I know that I’m not a robot?

- **Enduring Understanding:** While we can measure or observe certain physical phenomena which we see as correlated to consciousness, we cannot measure (or observe in others) consciousness itself.

### Core Knowledge and Skills from unit that lesson aligns to:

#### Content Knowledge:

1. Possible “tests” of consciousness:
   - a. Turing test (theoretical)
   - b. CAPTCHAs

#### Philosophical Knowledge:

1. Various terms and definitions: consciousness, subjectivity, awareness, awakeness, sentience, qualia - potential distinctions between these terms (what qualities of experience does each emphasize) and relationship to relevance of various tests and theories of consciousness.
   - a. Philosophical zombie (Chalmers)
   - b. Chinese room (Searle)

#### Skill:

1. Asking questions
2. Engaging in argument from evidence
3. Developing and using models
4. Perspective-taking
5. Guided imagination / Empathy
6. Counterfactual thinking
7. Self-knowledge, internal awareness, and meta-cognitive reflection

### NGSS

*MS-LS1-8.* Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

### Connection to Unit Performance Task

At the end of the unit, students will have a choice of creating a philosophical thought experiment, a theoretical test, or a guided meditation meant to illuminate questions and issues related to consciousness. This lesson will provide them with models of theoretical “tests” of consciousness (such as the Turing test) and build their skill in analyzing the presuppositions that “tests” of consciousness are based on. A core component of their performance task, regardless of what product they choose, will be relating that product to such presuppositions.
Lesson Level Specifics

<table>
<thead>
<tr>
<th>Title of Lesson: Tests of Consciousness, Part I</th>
<th>Time Spent on this Lesson: 4 days</th>
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</table>

Lesson objective: Learners will be able to...
- analyze proposed tests of consciousness in order to determine on what philosophical assumptions regarding consciousness they are based.
- apply thought experiments to proposed tests in order to critique these assumptions.

Lesson level question and understanding - what question will students explore and what concept will they attain as a step toward the unit EUs and EQs?

Lesson Question: What are some of the proposed tests for establishing that something is conscious, and on what assumptions regarding consciousness do they rest?

Lesson Understanding: All proposed tests for establishing the consciousness of some entity are indirect; rather than testing for consciousness itself, they test for some other properties or characteristics that the test designer implicitly or explicitly associates with consciousness. Philosophical thought experiments in response to these tests are often designed in order to illuminate and critique these assumed connections and highlight a potential distance or difference between the thing being tested for and consciousness itself.

Key points:
- Examples of “tests” of consciousness: Turing test (theoretical), CAPTCHAs (practical)
- Examples of thought experiments that serve as critiques of such tests: the Chinese room, the philosophical zombie
- Definitions of consciousness vary, but often include a connection to perception, information-processing, and/or internal awareness of external objects, as well as a focus on “qualia” - the sense of experiencing something as distinct from simply having information about (e.g. the difference between a sentient being feeling pain vs. a thermostat registering heat)
- There is disagreement regarding whether the different characteristics sometimes attributed to or connected to consciousness (e.g. perception, qualia, sense of being a self…) are really related or are in fact distinct and separable phenomena
- All “tests” require observability - consciousness must be defined as or related to something observable in order to be tested

Lesson Context

| Prior: Students will have participated in an opening activity to ground themselves in the EQs of the unit, and will also have | Post: Following this lesson, students will have initial book group meetings in order to make connections between conclusions of this lesson and their books. |
started reading in their book groups, so that different students will have some additional related knowledge regarding theories and science of consciousness to draw on.

They will then begin to explore relevant neuroscience (e.g. information processing in the brain, how brain activity is stimulated and observed) before learning about tests of consciousness from medicine (zap-zip) and analyzing them using the philosophical knowledge gained in this lesson.

**Assessment / vision of mastery**

Several activities in the lesson will serve as primary evidence as to the degree to which students are making progress towards the objectives, understanding, and key points listed above. They include:

**Diagnostic**
- Beginning of Day 1: Students individually sort/rank pictures based on their degree of confidence that the subject of the picture experiences “consciousness,” come up with initial ideas regarding the properties of consciousness based on this sorting, and come up with initial “tests” of consciousness based on these properties - what would they look for and how would they look for it? *Teacher should assess students’ prior knowledge and assumptions regarding the nature of consciousness, as well as what it means to “test” for something.*

**Formative**
- Day 1: Students work in groups to analyze a sample CAPTCHA using knowledge of various theories of consciousness - if the CAPTCHA is viewed as a test of consciousness, what does it reveal about the test designers position on some of the questions and debates within the philosophy of consciousness? How so? *Teacher should look for evidence of perspective-taking and arguing from evidence - to what extent are students able to make an evidence-based argument regarding the likely assumptions about consciousness of the test designer.*
- Day 2: Individually, students imagine themselves as a character in one of two philosophical thought experiments on consciousness and describe their reactions, thoughts, and feelings, and then analyze the Turing test using the thought experiment. *Teachers should look for evidence of imagination, empathy, and counterfactual thinking - to what extent are students able to use their imagined participation in the thought experiment to illuminate assumptions of the experiment, and to what extent are they able to identify the point of departure between the thought experiment and the Turing test regarding the nature of consciousness.*
- Day 3: Students work in teams to create their own version of a CAPTCHA or Turing test. *Teachers should look for evidence of asking questions and making arguments from evidence - to what extent are the students able to justify the questions they are proposing for these tests, given specific possible definitions or properties of consciousness.*

**Summative**
- Day 4: Students first imagine their reaction to “failing” a test of consciousness, and then go back to their responses on the initial Day 1 activity (see “Diagnostic”) and reflect on what these responses reveal about their own theories of consciousness, as well as the degree to which their thinking has evolved over the last few days. *Teacher should look*
for evidence of imagination/empathy and self-knowledge/internal awareness - to what extent are students able to project themselves into a strange scenario and speculate generatively and meaningfully about their possible responses, and to what extent are students able to see their own assumptions as revealed in their earlier work - as well as changes in their philosophical/content knowledge.

<table>
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<tr>
<th>Classroom set-up</th>
<th>Materials</th>
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| Flexible set-up - students will alternate between various small group activities, individual activities, and whole class activities. There will also need to be a way for 3 students to be hidden from view on Day 2. | • Devices (iPads/Chromebooks, cell phones)  
• Journals  
• Readings  
• Siri or Alexa on a device, Chatbot program  
• *Blade Runner* clips |

### 5E Lesson Plan

#### Day 1

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
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<tr>
<td><strong>Engagement / Opening</strong> – students’ prior knowledge accessed and interest engaged in the phenomenon (13 min.)</td>
<td>Students are given a series of pictures and asked to order them in terms of the degree of confidence they have that the subject of the picture experiences “consciousness” (pictures should include a picture of the student him/herself, a picture of another student and/or the teacher, a robot, an alien, a sleeping person and/or person in a vegetative state, a smartphone, a rock or other inanimate objects, various animals, a plant or other living thing, people engaged in different activities / with different expressions, a star or galaxy, a human brain, a human heart, a model of the atom, etc.). Each student should have ~10 pictures of varying types.</td>
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Students compare their pictures and rankings and discuss how they made the decisions they did. What factors did they have in mind? How did they feel in response to the pictures, and how did that impact their decisions?

In groups, students are invited to brainstorm a possible “test” of consciousness using the following two questions:

1. What evidence would you look for to tell if something is “conscious” (think back to the evidence you used to make decisions in the sorting activity)?
2. What could you do to gather / acquire this evidence?

Teacher explains that over the next couple of days, they will be looking at proposed tests of consciousness. Each test looks for certain evidence in certain ways. In a sense, each test is an attempt
to answer the question, “How do I know you’re not a robot?” (one of the unit essential questions).

Teacher goes over lesson question and end-of-lesson assessment task, and briefly explains the lesson agenda.

| Exploration (1) – students participate in an activity that facilitates conceptual change (14 min.) | Students will take part in several examples of CAPTCHAs (“completely automated public Turing test to tell computers and humans apart”) of the type used by websites to try to determine if the respondent is a human or a computer - for example, distorted text (word written in nonstandard font, not in straight line, possibly with line through it - have to determine what the word is) or picture-selection (“choose all the pictures with vehicles in them,” “choose all the pictures of farm animals,” etc.). For each one, students will make observations about the task itself, will consider how difficult they found it, will note their “success” (e.g. how long they took, if they had to repeat the test more than once before the computer was sure they weren’t a computer, etc., and, if so, how many times), and will think about how they feel taking the test.

Students will form groups based on the CAPTCHA they struggled with the most. In these groups, students will discuss:

- Their experience taking the test and what made it challenging
- What is this test actually testing for? I.e. what is the specific evidence being gathered?
- How does this / could this relate to consciousness?
- What do they think of this as a “test” of consciousness?

| Explanation (1) – students generate an explanation of the phenomenon (20 min.) | Teacher gives some background on these tests - not explicitly designed as tests of consciousness per se, but designed to distinguish between human users and computers. However, given that it is sometimes posited that consciousness or sentience is a fundamental distinction between human and computer (or robot), can also see these as potential tests of consciousness.

Students continue to work in groups to formalize their current understandings of the relationship between one of these tests and implicit notions regarding consciousness.

- They do this by first reading an introduction to theories of consciousness within philosophy and major questions/debates regarding the nature and distinguishing qualities or characteristics of consciousness.
- After completing the reading, students work in groups to
reflect on one of the CAPTCHAs and identify how the design of the CAPTCHA, if viewed as a test of consciousness, reveals an implied stance (ie. assumptions) on some of these questions/debates.

Teacher facilitates whole-class discussion. Each group shares its conclusions. As a class, students then discuss:
- Whether it would be possible to have a test of consciousness that did not rest on certain prior assumptions about consciousness such as those discussed in the reading
- Whether the philosophical assumptions upon which tests of consciousness rest can themselves be tested - how so or why not?

**Closing** (3 min.)

Students and teacher complete individual reflection in their journals, sharing their own responses to some of the assumptions, questions, and debates regarding the nature of consciousness illuminated by the readings. How does this compare to their own prior conceptions? Do any of the ideas or questions excite, frighten, confuse, or otherwise emotionally impact them? Why might that be?

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**Day 2**

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<tr>
<td><strong>Opening</strong> (5 min.)</td>
<td>Students and teacher silently read their journal responses from yesterday in order to remind themselves of their experiences and reactions. Teacher reminds students that the tests they looked at yesterday were called “CAPTCHAs,” and reminds them what that abbreviation stands for. Teacher then focuses on the term “Turing test” within the name. Explain that this is a classic test of computer intelligence, which they will learn more about shortly, after first participating in their own version of the Turing test.</td>
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<tr>
<td><strong>Exploration (2)</strong> – students participate in an activity that facilitates conceptual change (17 min.)</td>
<td>The class completes a simulation of the Turing test. Three students are hidden from view. The rest of the class takes turns sending a message to each of these three students (via text, email, or some other messaging system). One of the hidden students responds normally. Another responds by getting an answer from Siri or Alexa and sending that back. The third responds by getting responses from a more advanced Chatbot. Students then determine which of hidden respondents was/were human</td>
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and which was/were not. They also consider what questions and responses they found most revealing, and why. What does this say about their assumptions regarding consciousness? The real identities of the respondents are revealed, and students reflect on their prior conclusions.

If time, consider repeating the simulation, but with all three respondents being human (without letting students know this is the case). After revealing this fact, have students reflect on the second experience.

| Explanation (2) – students generate an explanation of the phenomenon (28 min.) | Teacher gives short introduction to Alan Turing and history of Turing test. Students then read about two thought experiments from philosophy that can be seen as responses to the Turing test: 1) the Chinese room; and 2) the philosophical zombie (or p-zombie).

Students pick one of the two thought experiments and imagine themselves as one of the characters in the thought experiment (e.g. the person following the code in the Chinese room experiment, a person encountering a “philosophical zombie”) and write out an imagined scenario, describing their thoughts and feelings. Students then get in pairs/trios and share a chosen excerpt and discuss what each one makes them think about the thought experiment, and about consciousness itself.

Students use their imagined scenarios as they apply their chosen thought experiment to the Turing test itself. Students will:

- Explain how the thought experiment serves as a critique of the Turing test as a test of consciousness - what does it reveal about the assumptions about consciousness embedded in the Turing test, and how does it respond to those assumptions?
- Share their own response to the thought experiment - what argument is it making regarding consciousness and evidence for it? How do they feel about this argument? What do they think of it? Why?
- If time, suggest an alteration to either the Turing test or one of the thought experiments. Explain why they suggest this alteration and what it reveals about their own beliefs regarding consciousness. |
### Opening (7 min.)
Students complete an initial activity in which they compare the two tests discussed (CAPTCHA and Turing test) in terms of evidence looking for, how evidence is gathered, and underlying assumptions regarding consciousness. Students discuss their responses as a class in order to remember some of the distinguishing features of each test and related philosophical theories of consciousness.

### Elaboration (1) – students’ understanding of the phenomenon challenged and deepened through new experiences (40 min.)
Students will work in teams to create their own version of one of the proposed tests of consciousness discussed so far (CAPTCHA or Turing test). Students working on the CAPTCHA option might, for example, try to come up with closed questions and answer options that might be particularly effective at spotting the difference between a programmed “intelligence” and a human with consciousness. If their prompt(s) include image-selection, they may choose to take photographs, make drawings, or search the web for images that might “trick” a computer but not a human. Students working on the Turing test option might generate a list of open questions where they expect the genuine response of a conscious person would be most difficult to program into a non-conscious machine, and then evaluate and order those questions, and perhaps plan follow-up questions based on type of response received.

### Closing (3 min.)
Students and teacher complete individual reflection in their journals. Describe their design process and identify one element of their design (e.g. a specific question or set of questions) they think is particularly strong, and explain why, given some of their own thoughts about consciousness.

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### Day 4

### Elaboration (2) – students’ understanding of the phenomenon challenged and deepened through new experiences (13 min.)
Each team of students will participate in another team’s proposed test. Then, teams meet to give feedback and describe their experience designing and taking each test. What thoughts about the nature of consciousness and evidence for it were driving the test designers? What thoughts about the nature of consciousness and evidence for it came up while taking the test? Do they think there will ever be a true test of consciousness, or even a partial test of consciousness (e.g. mostly accurate but would
give false-positives or false-negatives in a limited set of conditions)? If so, what would have to be true for this to be the case? If not, why not?

**Evaluation (1) – students assess their understanding of the phenomenon (27 min.)**

Watch a few clips of the original *Blade Runner* film - two clips of cyborgs taking part in the “Voigt-Kamff” test, one of the detective discussing the test results (for Rachael, the cyborg who does not know she is a cyborg), and one of the detective revealing to Rachael that her memories aren’t “real.”

In small groups, students discuss the following questions.

- Describe the “test” - what questions are used? What evidence is collected?
- What do you think is the significance of these prompts and this evidence? (Why these and not others? What are they looking for?)
- What does this have to do with “consciousness” and/or the difference between humans and machines? What assumptions does the test rest on?
- How is this test similar to and different from others we’ve studied?
- Is Rachael conscious? Why or why not?

Teacher then facilitates whole-group discussion. Groups share and compare major conclusions, as well as any significant points of disagreement or uncertainty within each group.

Students and teacher complete an individual reflection on the following prompts:

- If you were given a similar test and told that, according to the test, you are not conscious, what would you think? What would you feel? Try to put yourself into such a moment and write an inner monologue.
- Reflect on your own imagined reaction. What does it reveal to you about your own beliefs or assumptions regard the nature and meaning of consciousness?

**Evaluation (2) / Closing – students assess their understanding of the phenomenon (10 min.)**

Students go back to the very first activity of the lesson and review their initial responses. Based on their initial responses and their experiences and insights over the last few days, students will do the following in a written reflection:

- Discuss what their initial responses reveal about their own implicit positions regarding some of the questions of consciousness discussed over the last few days (its
definition/properties, degree to which different properties represent a single phenomenon, etc.)

- Evaluate their initial responses based on what they have learned. Would they respond differently now? How so / why not?
- Re-group the images into 4 piles: definitely conscious, probably conscious, maybe conscious, definitely not conscious. *(Emphasize that these groupings are based on their opinion, not right/wrong answers). Explain their reasoning.
- Give their personal answer to the following question: Could there be a definitive test of consciousness? Why or why not?

In a whole-class discussion, students will share a part of their final reflection.

### Additional Notes on Differentiation:

- Some students may keep an audio or video journal, rather than a written one. These students may record their reflections rather than write them down.
- For the imagination activities (putting yourself into a thought experiment, imagining yourself “failing” a test of consciousness), some students may find it more effective to initially respond through art, for example by drawing. Allow these students to also explain the thinking behind their visual work, through writing or orally.
- In addition to informational readings, provide alternative representations of the same information. This may include short videos or audio recordings.
- CAPTCHAs should include examples of CAPTCHAs for visually-impaired individuals (e.g. listening to and identifying a distorted sound). Students may likewise create such CAPTCHAs.
Annotated Resources and Materials

General Resources

Brooks, M. (2009). *13 Things that Don’t Make Sense: The Most Baffling Scientific Mysteries of Our Time*. New York: Vintage Books. Popular science book that discusses a number of phenomena which scientists are currently struggling to explain, including several related to topics of this curriculum: dark matter, dark energy, free will, and the placebo effect. Each chapter provides a short history which reveals what is mysterious or difficult to explain about a phenomenon or how it conflicts with established science, debates within scientific communities about potential explanations, and ongoing research efforts.

TED Ed Video Database - for students and teachers to develop familiarity with ideas explored in the curriculum (full text and subtitles available)

Pedagogical Resources

Teaching Science as Inquiry:

BSCS Science Learning 5E Resources (https://bscs.org/bscs-5e-instructional-model/): Overview of the 5E instructional model by BSCS (which developed the model). Includes several videos explaining the origin, evolution, and continued relevance of the model, as well as written reports documenting the origins and effectiveness of the model.

Tools for Ambitious Science Teaching (https://ambitiousscienceteaching.org/): Provides a comprehensive introduction to one very-promising approach to designing and implementing
units and lessons using a models-based inquiry cycle. Website includes primers and tools for supporting teachers in each of the core practices of this instructional approach - e.g., eliciting students’ ideas, pressing for evidence-based explanations, etc. Primers give an overview of the what, why, and how of each practice, and tools provide a more concrete template for applying the practice in a specific unit or lesson. Also includes an extensive video library showing students engaged in models-based inquiry, as well as additional tools for scaffolding student development in areas like speaking and writing and for supporting students in the development and revision of scientific models.

Jadrich, J. and Bruxvoort, C. *Learning and Teaching Scientific Inquiry: Research and Applications*. NSTA Press: This book introduces the idea that scientific inquiry can best be defined by its purpose (developing, testing, and revising scientific models of phenomena) and clarifies the characteristics that distinguish scientific models. The book contrasts a focus on model-making to other approaches to teaching inquiry in science classrooms and provides research-based evidence for this approach. It then gives a number of case studies of what models-based inquiry in science classrooms could look like, and provides concrete resources and strategies. This can serve as a primer for this instructional strategy, helping the teacher to distinguish it from other instructional approaches, understand the rationale behind it, and develop knowledge and tools to apply the strategy.

PhET Interactive Simulations: [https://phet.colorado.edu/](https://phet.colorado.edu/). Provides a large bank of interactive simulations through which students can develop and test predictions in order to determine patterns and relationships and construct fundamental scientific concepts. Provides a way for
students to engage in scientific inquiry in a virtual way even for topics which most classrooms do not have the resources to explore directly.

Concord Consortium STEM Resource Finder: https://learn.concord.org/. Similar to PhET (see above), provides interactive simulations through which students can develop scientific concepts for themselves.

Aesthetic/Embodied Education:

The Maxine Greene Institute (https://maxinegreene.org/): A community hub for practitioners of aesthetic education. Includes an overview of aesthetic education as proposed by Greene, models of current organizations practicing aesthetic education, and a library which lists works by Greene and other works on aesthetic education.

TED Talk on Embodied Learning by Camille Litalien (https://www.youtube.com/watch?v=_kl42b9B9yA): Makes argument for the value and importance of exploring through and awareness of the body and shares personal story of own growth in these capacities. Discusses use of dance, yoga, and other practices. Connects use of the physical body, heightened perception through the senses, and greater knowledge of the natural world. Litalien states that during embodied learning experiences, “I recover the ability for my mind to inhabit my whole body” and “all my senses become active.”

Biology Education 19(1). ([https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5969448/](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5969448/)): Discusses the role of arts, including both visual and performing arts, in improving science education, but also as a form of outreach to create greater general awareness of and interest in STEM fields. Describes what the integration of various forms of art into science learning might look like and provides links for exploring specific programs and activities that do this.

**Supporting Reflection/Introspection/Internal-awareness:**

Headspace ([https://www.headspace.com/](https://www.headspace.com/)): Basic resources for learning about meditation and how to meditate. Provides numerous examples of guided meditations. Can be used directly, or as a model for developing other guided meditations.

Mindful ([https://www.mindful.org/](https://www.mindful.org/)): Basic resources for learning about meditation and how to meditate. Provides numerous examples of guided meditations. Can be used directly, or as a model for developing other guided meditations.

**Metacognition: Nurturing Self-Awareness in the Classroom** - this article explains how to develop metacognition in the classroom through eight core ideas (one of them being using journaling to monitor students’ thinking)

**Unit-Specific Resources**

**Introductory and Culture Setting**

Twilight Zone Episode: The Parallel 1963 ([https://www.dailymotion.com/video/x2edutu](https://www.dailymotion.com/video/x2edutu))
NASA Hubble telescope images: teacher will use various digital or hard copy images of space/stars/planets in the Elaboration phase (day two)

Van Gogh’s Starry Night: this famous image can be used by teachers as an image for students to view during activity.

Rubber hand illusion: this trick used in the Engagement phase (day two) will help students understand the ways in which the brain is making its best guess at reality by the ways it takes in information

Checkerboard illusion: this illusion used in the Engagement phase (day two) will help students understand the ways in which the brain is making its best guess at reality by the ways it takes in information

What else is out there?: Dark Matter and Dark Energy

Car Horn Doppler Effect: This video shows a car passing by a camera that records sound and we hear the frequency of the sound change.
An ultimate theory?: Quantum Physics and Relativity

Sunlight Diffracting Through Clouds (http://www.lambofgodctn.org/from-the-pastors-desk/31917)


The above three images are examples of light diffraction occurring in different settings.

Simulation Settings Image

Double Slit Diffraction Simulation Website (https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html). This website provides a very nice platform for students to observe the double slit experiment online without requiring the necessary (very expensive) lab equipment that is used to perform the experiment in real life.
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Single Electron Double Slit Experiment Results

(https://www.youtube.com/watch?v=ZqS8jkk1HI) Video that shows the final locations of single electrons on a screen after being shot through a double slit.

Who’s Really In Control?: Human Determinism and the Brain

The Island Where People Forget to Die (NY Times article): used as a case study resource

(https://www.nytimes.com/2019/01/19/us/yoga-veterans.html) - remarkable case of a man living beyond his short cancer prognosis by moving back to Greek hometown

Yoga and Veterans: A Different Kind of Warrior (NY Times Article): used as a case study resource (https://www.nytimes.com/2019/01/19/us/yoga-veterans.html)

Meditation’s Effects on the Mind & Body (NY Times Article): used as a case study resource (https://well.blogs.nytimes.com/2016/02/18/contemplation-therapy/) (NY Times Article)

What if the Placebo Effect Isn’t a Trick? (NY Times Article): used as a case study resource


Content Resources

American Cancer Society: Placebo Effect (https://www.cancer.org/treatment/treatments-and-side-effects/clinical-trials/placebo-effect.html): this article gives background information on the placebo effect phenomena
"Placebo: Cracking the Code" (https://youtu.be/QvbQnMvhQFw): Youtube video that explains the historical background on Placebo Effect. Could be used with students or for teachers to gain a deeper understanding of the history before the lesson begins.

TedED: Placebo Effect (https://ed.ted.com/lessons/the-power-of-the-placebo-effect-emma-bryce): accessible and easy to navigate website for teachers and students containing an open discussion, and additional resources such as articles and videos on the placebo effect

TedMED video on Placebo Effect - similarly to a TEDx talk, this video has a presenter explain the placebo effect through talk and slideshows

“Am I a Robot?”: The Science of Consciousness

For use in student book groups:

Bauby, J. D. (1997). The diving bell and the butterfly: A memoir of life in death. (J. Leggatt, Trans.) New York: Vintage International. Memoir of the author, who, following a stroke, was left almost entirely paralyzed, and who was eventually able to communicate by blinking one eye. Prior to learning this method, his caregivers and companions had little idea of what his internal state was - how much he perceived, experienced, thought, etc. A profound account of what it means to be internally aware but have almost no capacity to share that awareness with others. Raises questions regarding the observability of internal, subjective phenomena and alludes to potential consequences of assuming consciousness can be observed.
Godfrey-Smith, P. (2016). *Other minds: The octopus, the sea, and the deep origins of consciousness*. New York: Farrar, Straus and Giroux. This book combines science and philosophy, using observations from the lab and the wild to argue for the possible consciousness of cephalopods, and from that argument, to develop hypotheses regarding how early in the evolution of life forms consciousness may have arisen and the factors that may have driven the evolution of consciousness. It suggests that two factors - movement and sight - are the key to understanding the nature, purpose, and origins of consciousness.

Montgomery, S. (2015). *The soul of an octopus: A surprising exploration into the wonder of consciousness*. New York: Atria Books. Similar to Godfrey-Smith (above). Takes readers into the world of the octopus in order to challenge assumptions about how similar to or different from us they really are. Opens up questions about what other beings may be conscious and how their experience of consciousness might compare to ours.


**Other student-facing materials:**

Gendler, A. The Turing test: Can a computer pass for a human? TEDEd.

video included in this sample lesson on the Turing test can serve as a good introduction to the test for students. Also provides additional resources for student exploration in the “Dig Deeper” section.

Alimardani, M. Are you a body with a mind or a mind with a body? TEDEd. https://ed.ted.com/lessons/are-you-a-body-with-a-mind-or-a-mind-with-a-body-maryam-alimardani: Short video included in this sample lesson gives an introduction to a central problem or question of consciousness (the mind-body relationship or dualism) and discusses attempts by major philosophers to address it. Could be used as part of an introduction to philosophical discourses about consciousness. Also provides additional resources for student exploration in the “Dig Deeper” section.

For additional information on theories of consciousness:

Blackmore, S. (2010). Consciousness: An Introduction. (2nd ed.). New York: Routledge. Brings together theories of consciousness spanning various traditions, including those from Eastern and Western philosophy, neuroscience, and quantum theory. Comprehensively references major figures, problems, and concepts in the history of theories of consciousness, and touches on not only the nature of consciousness, but its origins in the brain and in evolution. Each chapter not only illuminates a major concept and problem, and key contributor, in discourses around consciousness, but also includes a suggested practice and activity for readers to illustrate the concept and problem.

Oxford University Press. Chalmers is the originator of “the hard problem of consciousness,” the notion that explaining our sense of an internal experience is a fundamentally different problem to explaining how specific functions associated with consciousness - e.g. the ability to perceive and process information - arise, and that no amount of attributing these functions to specific physical mechanisms will be enough to solve the “hard problem” of how we come to have an experience of, rather than simply information about, something. In these books he argues for the incompleteness of biological conceptions of consciousness, the need for (and possibilities for) an entirely different conception of consciousness, and the potential applications of this new conception of consciousness to areas including quantum mechanics.

Dennett, D. C. (1991). *Consciousness Explained*. Boston: Little, Brown and Company. Dennett’s view of consciousness differs greatly from Chalmers’. He rejects the notion of qualia - the sense or experience of something as distinct from mere perception of it - and therefore suggests that there is no “hard problem of consciousness.” This book presents one of the strongest arguments for consciousness as a phenomenon that can be explained purely in terms of the physical mechanisms through which it arises.

Searle, J. R. (1990). *The Mystery of Consciousness*. New York: The New York Review of Books. Searle argues that a common misunderstanding among philosophers with very different theories of consciousness is that if we grant the real existence of subjective experience as something unique, we are essentially accepting a nonscientific dualistic view. In contrast, this book attempts to put forth a new way of thinking of consciousness as both deeply subjective and also purely natural and biological. Discusses some of the other philosophers of consciousness included here, particularly Chalmers and Dennett.
Annotated Bibliography

Introduction

Our annotated bibliography is guided by 1) an innovative vision of science that we want to open our students to, 2) the disciplinary context to which conceptions of science have traditionally been bound, and 3) the political context that reveals why science education has been shaped and molded to its current form.

Disciplinary Context

Our curriculum design is intended to both build from and challenge traditional conceptualizations of science, particularly as an academic discipline taught in schools. In order to prepare ourselves to design such a curriculum, we sought out perspectives on the philosoph(ies) and histories of science, as well as views on science teaching that are currently in vogue. By building a greater understanding of the philosoph(ies) of science, we hope to position ourselves to design a curriculum that makes these philosophies explicit for students, engages students in comparing the real history of scientific research and “progress” to idealized school representations of science, and empowers students to “talk to” (and “talk back to”) science as a way of knowing and to reimagine what a scientific epistemology might be. In consulting some of the texts that were foundational to the creation of the Next Generation Science Standards (NGSS), our aims included preparing ourselves to critically apply and build off of these standards, and further understanding the goals and assumptions that guide current K-12 science education so that we can strategically respond to them.

Political Context

In a setting of mass standardization, fastidious objectives and specific learning outcomes, science education has been constructed as a rigid practice of guided problem-solving and static
transmission of very specific ways of thinking about the natural world. Such practices are a result of a political context that is increasingly influenced by hegemonic free market ideas, which attempt to transform education to a market governed by neoliberal ideals. Standards, objectives and learning outcomes are given such a heavy emphasis because they are measurable. To say measurable is another way of saying quantifiable, and to transform learning into a process of meeting quantifiable criteria allows for education—as an institution of learning—to be transformed into just another market within the global economic system, a market that can be invested in and profited from. Having a foundational understanding of such a political context allows the bigger and broader forces that shape science curriculum to inform our understanding of why science education has taken its current restrictive form, and to guide both 1) how critically we read and adopt standards within our curriculum and 2) how we create our own objectives and learning outcomes.

**Vision**

We have thus chosen to center our curriculum around the open-ended and playful question - *what is truly unknowable in science?* We aim to challenge current interpretations of science as rigid, static and certain into new territory, by playing along the ‘fringes’ of new and mysterious scientific territory. Our curriculum is guided by the idea of bringing a pleasurable to science, so that students may satisfy their deepest curiosities about the cosmos and beyond. We hope our science curriculum will inspire educators to return to the child-like learners that perhaps initially engaged them with scientific questions! Our curriculum is also grounded in the belief that we can trust students to explore and contemplate complex phenomena. Given this, we sought out texts that expanded our notions of aesthetics, pleasurable, creativity, and spirituality in education in order so that it may inform our curriculum design.
Gathering insight into the disciplinary and political backgrounds that have shaped science curriculum in schools today will help guide us to make critical and strategic choices when designing our curriculum. Drawing from theoretical frameworks will allow us to strengthen our curriculum vision and ultimately align us towards a new vision of science curriculum that can stand alone as an interdisciplinary and engaging supplement to in school science curriculum.

**Disciplinary Context: History and Philosophy of Science and Dominant Perspectives within Current Science Education**


This book provides an introduction to the major questions explored within the philosophy of science and competing views among philosophers of science regarding how best to answer those questions. Philosophy of science, according to this text, “has the aim of answering those questions raised by scientific activity that are not directly addressed by science itself (p. vii).” These include questions about the goals of science as a human enterprise, the practices and underlying principles of science, the relationship between various scientific disciplines, and the relationship between science and reality. This text addresses major topics within the general philosophy of science (including scientific explanation, confirmation, and causality), as well as philosophies specific to various branches within science (such as the philosophy of logic, of physics, and of biology). It also compares the philosophy of science to other approaches to describing and analyzing the scientific enterprise, namely historical and sociological approaches.
Of particular interest to our curriculum design are sections on the metaphysics of science, on scientific change, and on “reduction and emergence,” that is, the degree to which various scientific theories are unified and point to a single picture of reality, or if not, “should we infer from their disunity that reality is ontologically plural in some way (p. 285)?” What this entire text reveals is that, contrary to the common sense view often advanced within K-12 science classrooms (and even by many practicing and highly accomplished scientists), there is not a single, agreed-upon understanding of the nature of science, including: the degree to which scientific theories do, can, or ever will give us a complete picture of “reality”; whether science presupposes or depends on a unified reality; and how scientific understanding changes over time, whether this change should be viewed as “progress,” and the degree to which the history of scientific change confirms or challenges a view of science as unified either in its depiction of reality or in the principles by which it operates. The information contained in this text will be of use in our curriculum design in a few ways. First, it will help us develop a framework for students to think meta-cognitively and critically about the nature of science itself, something mostly neglected in traditional science curriculum. Second, the competing viewpoints presented in the text will be a resource to us in illustrating that, contrary to the common sense view advanced in schools, the “nature of science” may not be a single, agreed-upon thing. Third, reflections on the (debated) nature of science, and particularly the possible relations between science and reality, can serve as springboard for student imagination and help to illuminate the value, even necessity, of “ways of knowing” not deemed “scientific” in a strict, or traditional, sense.

This article contrasts two ways of thinking about the relation between conceptual systems and sense experiences – a “cognitivist” or “intellectualist” approach, on one hand, and a “phenomenological” or “aesthetic” approach on the other. The author grounds his analysis in the philosophies of Dewey, Husserl, and Marleau-Ponty, all of which attempt to develop a non-dualistic perspective on the relationship between human beings / human experience and nature. He argues that the dominance of cognitivist perspectives in the research and practice of science education “contribute to an ‘anaesthetic’ and alienated view of nature (p. 131).” In contrast to this, the article advocates for the integration of “aesthetic” approaches to science education, defined as “a point of view which cultivates a careful and exact attention to all the qualities inherent in sense experience (p. 130).” Essentially, the author argues that nature speaks to us in many languages, and that one of the effects of the “scientific revolution” has been to make us deaf to many of those languages, as we privilege only the quantifiable aspects of sense experience. By returning to direct sense perception as a holistic experience that contains its own meanings and potential knowledge, the author claims that science education can not only improve students’ understanding of scientific concepts, but also combat students’ experience of alienation from nature.

This article helps elucidate the ontological and epistemological underpinnings of current science education, and to suggest alternative frameworks for the construction of scientific
knowledge. As such, it will help inform our critical reading of privileged perspectives and resources related to science education (such as Next Generation Science Standards and the NRC Framework upon which they are based) that will help us develop a curriculum that is both grounded in and a potential counter to these perspectives. The “phenomenological” approach to knowledge-construction it advocates for may also serve as one guide in our curriculum design, given our purposes of making room for multiple ways of knowing within the science classroom and encouraging multiple ways of exploring and responding to the physical world. Because the “aesthetic” or “phenomenological” point of view, as defined in this article, emphasizes the experience of “presence (p. 140)” during encounters with phenomena that provoke true learning and the holistic nature of sense perception (in which we see, hear, feel, etc. all at once, directly, without the imposition of categories or classifications), the integration of this approach into our design may help us create learning experiences that align with the expanded outcomes that we seek for students, particularly pleasure and wide-awareness.

National Research Council (NRC). (2012). A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, D.C.: The National Academies Press. This is the primary framework guiding the development and implementation of the Next Generation Science Standards (NGSS). As such, it captures much of the current “common sense” regarding the teaching of science in K-12 schools among educators and curriculum designers. For the purposes of our curriculum project, this “common sense” is significant both for the ways in which it represents a departure from traditional science teaching, and the ways in which it preserves certain assumptions un-girding traditional
science teaching. Among other things, the Framework lays out a vision for K-12 science education (i.e. what are the purpose and aims of general science education at this moment in American history), specifies a conceptual framework for the development of new science standards and curricula, and identifies certain principles that underlie this conceptual framework. The Framework argues, among other things, that science standards and curriculum should be designed in such a way as to be relevant and useful for all students, while also giving a strong foundation to those who may be interested in careers in science, engineering, and related fields. Another significant contribution of the Framework is its emphasis on the full integration of established scientific knowledge with the practices needed to engage in scientific inquiry and engineering design. The Framework lays out a list of eight “practices” of science and engineering which the authors argue should be fully embedded into science standards, learning experiences, and assessments.

The Framework will inform our curriculum design in several ways. First, elements of the vision contained in the Framework support the aims that we are seeking to address (for example, there are references to the importance of students experiencing the beauty and wonder of science), providing support for our rationale. Given the stature the Framework enjoys among many science educators and education leaders, this will be useful to providing legitimacy to our (perhaps subversive) curriculum. Second, while elements of the Framework do support our own curriculum vision, the Framework as a whole reveals some of the gaps we are seeking to address. So, while the Framework makes some mention of more subjective aims or outcomes (e.g. appreciation of the natural world),
these appear inconsistently, while references to more “practical” aims of science education (engaging in public debate, consumer decision-making) are often predominant. Recognizing both the overlap and the difference between the vision of science education spelled out in the Framework and the vision we are seeking to advance in our curriculum design will enable us to be both critical and strategic in our use of the NGSS. In addition, the conceptual framework for the design of science standards laid out in this document will be an important reference for us as we seek to modify or supplement existing standards and develop our own standards as part of our curriculum design.

Political Context: Political Structure and Context that has shaped Science Education


Weinstein argues that the NGSS (New Generation Science Standards) are deeply embedded in a neoliberal system of knowing and operating, while at the same time having elements that oppose it. He begins with a theoretical framework that focuses on the phenomenon of disposability that neoliberalism ratifies. In referencing Harvey’s analysis that a neoliberal system will look to create markets where none exist, he declares that it is the nature of the individual human being that is transforming—the human is now in a state of constant and continuous search for the next big opportunity or idea to invest in and profit from. In other words, neoliberalism creates an ethic of personal responsibility that forces people into adopting an entrepreneurial spirit, and if an
individual feels that they have not adopted this spirit and fulfilled this responsibility, they feel disposable.

The NGSS’s implication in a neoliberal system of economic governance is shown by Weinstein to be done in two ways, one being more significant than the other. The first is through the direct influence of testing companies. Weinstein reveals that during “a review of the pre-release standards” he asked why “so many of the standards seemed very picayune and narrow in their technical focus,” with the response being that “such narrowness was a result of the direct intervention of testing companies” (p. 825). The second and more significant way is through the infusion of engineering principles and practice throughout the NGSS, which emphasize the power of technical fixes for solving problems. The nature of technical fixes, however, ignore the political and social dimensions of an issue and reduce “the social and political costs in a strange epistemological act of bad bookkeeping” (p. 826). What this achieves, according to Weinstein, is the perpetuation of the same social and political issues that first caused the problems which technical fixes are attempting to solve. As a result, neoliberalism is deeply embedded in the NGSS standards: standardization transforms learning into metrics that can be used in the “production of national markets for educational goods and services”, and it “imposes a grid of legibility on the complexity of the student body” (p. 827).

Weinstein also analyzes how the NGSS also go against neoliberalism, which completes his overarching point about the ambivalence of neoliberalism towards science. As mentioned previously, although the standards do not necessarily tackle social and
political issues from the necessary social and political lens, a framework of care and egalitarianism can be seen interspersed throughout them. The beginning statement of purpose of the NGSS does promote the importance of markets and global competition, but it also suggests that the standards aim to make science seem useful and meaningful on a more personal level as well. Weinstein was sure to note that this is all done on a surface level, however, showing how issues such as climate change and cultural inclusion were brought up within a framework of “complete denial of structural forces that lead to contested visions of science” (p. 831).

As such, this article shows the dual function of the NGSS in both 1) being implicated in a neoliberal system and 2) being in a “privileged position in the theorizing of the neoliberal ideoscape” (p. 824).


Komljenovic & Robertson highlight the processes through which education markets are made. The two most relevant for the purposes of our curriculum framework are 1) the creation of education market devices and 2) the strategies for education market making. Understanding these processes helps reveal the “powers and interests [that are] at play” and “challenges… the basis on which these processes” are assumed to be implemented (p. 289). Namely, it builds on Weinstein’s (2017) ideas by exploring the structural manifestations of neoliberalism.

The first process highlighted is the creation of market devices. Standardization, digital technology and infrastructure, and data are the main market devices outlined, and each
has been shown by the authors to serve a specific purpose. Standardization serves to make the teaching and learning process more rational and therefore more efficient, digital technology and infrastructure “enable ways for markets to work, expand and represent immense and as yet unimaginable opportunities. But most importantly, it is lubricating, enabling and providing opportunities for the creation of new markets and commodities” (p. 291-292), and data infuses the education market with a discourse of objectivity and trustworthiness that legitimizes it.

The strategies for education market making, which compose the latter of the two processes I am covering from Komljenovic & Robertson, occur through the colonization of space and time. Actors interested in creating education markets look for spaces and places that are lucrative for and amenable to these markets, and the case of Liberia is presented as an example, where their education minister was “willing to outsource Liberian education to for-profit actors, even in the face of international outcry” (p. 292), making Liberia an ideal space for the making of an education market. Time is colonized as well, in the sense that the nature of education as an avenue for social mobility is exploited for the purpose of framing a conception of the future that sees investment in and success of the education market as vital.

Robertson & Verger’s (2012) chapter, entitled *Governing education through public private partnerships*, introduces how neoliberalism is pushed for and operated at a macro-level between different public and private actors. The discussion begins with a reference to a small network of four individuals who authored a handbook about PPPs in education that was released by the International Finance Corporation (IFC) in 2001, an organization dedicated to “unlocking private investment, creating markets and opportunities where they’re needed most” (International Finance Corporation, n.d.). This small network is said to be “behind the most well known publications, policy-briefs and toolkits on ePPPs”, and is characterized as “quite narrow in scope, but very cohesive. As observed in the publications and events identified, their members write and speak at each other’s initiatives” (p. 29). Most glaringly, however, is the “central assumption made by this policy network… that education is a consumer good, and that the student is the principal consumer through parents” (p. 29). In other words, there exists a policy network, composed of an extremely small group of individuals who are being used by a major international agency to release handbooks, publications and other documents that argue for a push towards public private partnerships in education, but whose view of education is quite deficit: it is a consumer good, a commodity, to be consumed by families, and the goal of public private partnerships is to treat them as such. The resultant rise of PPPs in this form changed the governance of education in ways that allowed the rise of a private authority that is “deeply embedded in the heart of the state’s education services at all levels, from policy and research work to delivering learning in classrooms” (p. 37). The initial framing of ‘partnerships’ that PPPs in the education sector sought to draw on was presented as a fix for having either ‘too much state’ or ‘too little state’ in
any given sector, but the reality of how PPPs actually manifested illuminates that they were merely a friendlier semantic for forcing in a neoliberal agenda in the education sector: “In relation to the use of ePPPs in governing the education sector, we need to be wary of viewing partnerships as simply technical tools. This they are not. EPPPs are fundamentally about social and economic relations” (p. 38).

Vision: Towards valuing spirituality and pleasurability in the Science Classroom


Students bring an innate sense of curiosity with them into the classroom, and so, Carr and Haldane argue that it is teachers responsibilities to provide the space for this natural sense of wonder to unfold. The authors go on to claim that students in fact may lose interest in schooling when they perceive no intrinsic value for learning, noting that teachers often avoid addressing the ‘big questions in life’ in the classroom, which may actually lead to students seeking meaningful yet dangerous experiences outside of the classroom. The authors argue that the barriers to implementing a spiritual curriculum are: 1. “There is no general social agreement on what public schools should be for”, and 2. The nature of schooling is structured and outcome-oriented (centralised, beauractraic, control-oriented structure).

The barriers to implementation discussed by Carr and Haldene will help us imagine how this curriculum might exist in an actual school context. The tension discussed around not being able to define spirituality might allow us to play with certain aspects of our
curriculum design process - for example, it may serve to expand our content possibilities, yet limit the ways students are able to interact with them in other ways. Additionally, because there is evidence that students bring with them an innate curiosity, our curriculum might be shaped to combat traditional approaches that do not first seek out student ideas and interest in the beginning of a lesson or new topic.


This text discusses pleasure in relation to the cosmos and psyche. Ferguson (2005) refers to the differences between cosmos and psyche as a “relatively recent and peculiarly western division between” the cosmos as “an external and objective order of the material universe” and psyche as “an internal and subjective world of personal experience” (p. 2). Ferguson argues that these two ideas can only be understood in relationship with one another through social experiences. Ferguson believes that society is perpetually interested in movement towards greater rationality and social order, and this is why children, who represent chaos, playfulness, and a purely transitional state of development with regards to their intellectual capabilities, stand in contrast to this larger societal order.

With those traditional views in mind, Ferguson’s argument will help support our vision for this curriculum project to value and trust students intellectual capability away from purely a direction towards reason, but in order to continue nurturing a state of play and ‘chaos’, which is a point of departure from the traditional perspective on the purposes of education.
In this foundational text on spirituality and education, Miller and Moore discuss how the primary purposes of education have been towards economic preparation and serving materialism. The authors argue for a shift in education towards the whole child and reclaiming our souls. Soulful education is not just about the soul being part of students in the classrooms, but also that teachers and administrators should nurture their souls as well. Soulful education means teaching content and skills, and bringing balance between our inner and outer lives. Miller and Moore write that by acknowledging the soul in the classroom, we can address the big questions in life that continue to evolve with us throughout our lives. Among the strategies the authors suggest for nurturing the inner lives of children are: 1. Meditation 2. Visualization 3. Working with dreams and 4. Journal writing.

Some of the practices mentioned, particularly journal writing, may serve as future activities or entry points for ‘spiritual’ activities as we shift our students focus towards learning for pleasure and drawing out students most inner curiosities and questions. By discussing the cosmos and unexplained phenomena in our science curriculum, we hope to nurture a piece of students that is often left out of the curriculum, a connection to the inner mysteries or soul of the students that Miller and Moore discuss.

The focus of this article is condensing the theories of the late Japanese-Canadian education scholar, Ted Aoki. Aoki was interested in the spaces between curriculum as technology, defined as an orientation towards efficient end products, and theology, conceptualized as “value centered, growth oriented for the learner” (p.19). Aoki argued against curriculum as a ‘means to an end’, highlighting the Western prioritization with materialism. Instead, Aioki leaned towards injecting spirituality into the curriculum which is described as putting “a premium on the spirit, self, and being, or inner space” (p.21). Aioki encouraged teachers to develop the true spiritual nature of their students, especially in relationship with their peers, using the site of a cathedral as a metaphor for school as a place for this spiritual becoming.

Aoki’s techno-theological curriculum is centered around three main aspects: bridge, multiplicity, and tensionality. Aoki defines curriculum as bridge in the ways the curriculum lies in between the space of technology and theology; multiplicity as the process of decentering ourselves from technological instrumentalism; and tensionality as the flux between planned and lived curriculum. Aioki’s ideas of curriculum as bridge, multiplicity and tensionality will help the ways we think about and create assessment. Aioki’s ideas will remind us to balance both standards and the aesthetic or pleasurable aspects of our curriculum, both the importance of measurable assessment and aligning to standards, as well as appealing to the spirit of the student.
Other References


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