Chapter 13: Understanding the Philosophy of Science

Background

The philosophy of science builds upon epistemology, but often proceeds through an historical survey of the sciences and their processes of arriving at scientific truths. Here, you may need to supplement some of the historical background, found in encyclopaedias and videos on science (e.g., the Copernican Revolution in the Renaissance). To ensure students stay focused on the philosophy of science, pose second-order questions about science, such as those listed on SE p. 319. Introduce recent scientific discoveries or controversies to freshen the discusion.

About Chapter 13

Opening with the problem of whether astrology is a science sets the stage for differentiating science from non-science, or separating science from prescience (e.g., the pre-Socratic natural philosophers) and pseudo-science (dowsing or crystology). After a brief review of some major scientific thinkers, modern science is characterized through presentation of scientific method, and then critiqued by those who are suspect of whether this makes science a unique or supreme domain of knowledge. Lastly, students are exposed to several schools of thought in the philosophy of science, which they explore more deeply in the following chapter.

Features

In this chapter, the following features are included to help students make personal connections and/or deepen their understanding of the philosophy of science. You may use all or some of these features as explained in the table that follows.

Feature	Student Textbook Page(s)	Opportunity for Assessment	Strategies for Classroom Use
Your Unit Challenge	315	Self-assessment in relation to learning styles (Gardner's multiple intelligences, discussed in Chapter 12): Ask students at the start of the unit if they think the philosophy of science would be interesting, and why. Is their view based on their aptitudes or intelligences? Ask students to reappraise their answer after completing Unit 5. Some students who dislike science might be surprised at their interest here, and some students who like science may find they don't care for its philosophical investigation.	Since students may now tire of this activity, play with it: Have students write their question like a horoscope (e.g., As a Leo, your sentimental side will lead you to empathize with those left behind by a paradigm shift.)

continued

BIG IDEAS

- The philosophy of science is different from natural philosophy and from science itself, as a subject that raises second-order questions about science. (SE p. 318)
- As with logic, reasoning in science may proceed inductively or deductively. Philosophers of science are divided on whether science is basically inductive, deductive, or something best looked at in practice and aside from these dichotomies. (SE pp. 321, 329-331)
- As with metaphysics and epistemology, philosophers of science have to base their theories on certain assumptions about reality: whether scientific propositions mirror an independent and external reality, or whether we are always constructing scientific knowledge based on our cultural and historical immersion, with limited access to external reality. (SE p. 328)
- Science undergoes revolutions, or paradigm shifts, which calls into question how or if science progresses, and whether it is best studied through a sociological and historical lens. (SE pp. 332-333)

Feature	Student Textbook Page(s)	Opportunity for Assessment	Strategies for Classroom Use
Thought Experiment	336-337	The question on SE p. 336 asks students to investigate probability as a topic related to induction, which could form the basis for a writing assignment (research paper). Ian Hacking wrote a book on this topic, called *The Emergence of Probability: A Philosophical Study of Early Ideas About Probability, Induction and Statistical Inference*.	Ask students to consider how this discourse of probability has entered into their lives today. Consider the car insurance rates paid by males under 25 (see SE p. 342) for the carry over into Chapter 14 and its connection to induction. Risk minimization governs whether field trips can run, or whether the school can sponsor a football team. Is actuarial science like this really a science? How reliable are its predictions?
Viewpoints	334-335	Consider the subject of this feature a rich journal topic, perhaps connecting it to the "Making Connections" feature in Chapter 12 (SE pp. 298-299).	Consider showing the segment of the film *Examined Life* in which Appiah appears, to provide students with a sense of who he is as a philosopher. This might help to avoid making him something of an exotic specimen, straddling two worlds.

Learning Goal

Students will be able to distinguish the philosophy of science from either science or natural philosophy, and will also arrive at criteria for distinguishing science from non-science and pseudo-science.

Teaching Plan 1 (SE pp. 314-328)

Activity Description

Using inductive learning exercises, students explore the rules by which we distinguish science from non- or pseudo-science. Critical examination may lead to a reversal of these rules as the unit progresses (see Chapter 14), assisting students to formulate arguments for the grand debates to come at the end of the unit.

Assessment Opportunities for Chapter Questions

The table below summarizes assessment opportunities for selected chapter questions, including questions in the Chapter Review, which are relevant to this teaching plan.

Assessment Type	Assessment Tool	Section Questions	Chapter Review Questions
Assessment for Learning	Group brainstorming of other questions related to the philosophy of science	SE p. 320	
Assessment for Learning	Self-directed research as an extension of learning	1-3, SE p. 324	
Assessment as Learning	Self-directed research as an extension of learning	1-3, SE p. 328	
Assessment for Learning	Presenting in creative formats (DI)		1-2, SE p. 338
Assessment for/of Learning	Writing up research or journals		6-8, SE p. 339
Assessment as Learning	Self-directed research as an extension of learning		9, SE p. 339

Resources Needed

Make copies of these Blackline Masters:

- BLM 13.1 Unit 5 Culminating Activity: Philosophy of Science Debates
- BLM 13.2 Inductive Learning Activity
- BLM 13.3 Zodiac Signs and Personality Traits
- BLM 13.4 Piecing Together the Scientific Method
- BLM A Venn Diagram
- BLM C Comparison Chart

Timing

225 minutes
(three 75-minute classes)

Learning Skills Focus

- Independent work
- Self-regulation

Possible Assessment of Learning Task

See Teaching Plan 2 for this chapter's assessment of learning task.

Assessment (For/As Learning)

As teachers move through each chapter, opportunities will be highlighted to provide assessment for/as learning in preparation for assessment of learning at the end of each chapter.

Task/Project	Achievement Chart Category	Type of Assessment	Assessment Tool	Peer/Self/ Teacher Assessment	Learning Skill	Student Textbook Page(s)	Blackline Master
Unit challenge	Thinking	For	Self-directed inquiry	Self	Independent work	315	
Is astrology a science?	Application	For	Group inductive learning exercise	Peer	Collaboration	315	BLMs 13.2 and 13.3
Comparing thinkers	Knowledge	For	Self-directed inquiry	Self	Independent work	324, questions 1-3	BLMs A and C
Assembling scientific method from its component parts/ terms	Application	As	Self or group inquiry: flow-chart could be constructed to show sequence	Self; peer	Collaboration	326, margin question	BLM 13.4

Prior Learning Needed

Students will benefit from drawing upon their experiences of using the scientific method in science class.

Teaching/Learning Strategies

1. Hand out BLM 13.1 to show students the Unit 5 culminating activity. Discuss reasonable timelines for preparing for the final debates.
2. Before students even open their textbooks to the Unit 5 Opener on SE p. 315, give them a copy of page 1 of BLM 13.2, to see if they can *inductively* arrive at the concept defined by the rule. Concept acquisition is an inductive method of learning whereby students examine statements that "fit the rule" for the concept, or that define it, in comparison with statements or examples that "break the rule," or go outside the limits of the definition. Though time consuming, this activity triggers the pattern-seeking part of the brain and promotes the habit of examining terms—seeking the criteria for inclusion, or the rule, that determines which descriptors belong to which terms. If students get stuck on page 1 of BLM 13.2, give them page 2, which

may make it easier for them to arrive at the correct answer. (**Note**: on BLM 13.2, astronomy *fits* the rule; astrology *breaks* the rule.)

Next, have students read SE p. 315, the Unit Opener, to see what they think about astrology as a science. Then give them BLM 13.3, and ask if they think their horoscope as described on BLM 13.3 fits their personality. (**Note**: The Sun-sign descriptions were rearranged on BLM 13.3 so they don't match the months intended. The zodiac descriptions were rearranged such that each was moved ahead by *four months*, making Aries into Leo, Taurus into Virgo, and Sagittarius into Aries, etc.)

The purpose of the activity on BLM 13.3 is to demonstrate the concept of *confirmation bias,* in that many people are predisposed to accept the evidence (even though it is intentionally flawed).

The inductive learning exercises in BLMs 13.2 and 13.3 are intended to set up further discussion of induction in Chapter 14, one focus of which is the problem of induction. Inductive learning is an approach recommended by Barrie Bennett and Carol Rolheiser from the Ontario Institute for Studies in Education, University of Toronto. The approach, based on the early writings of Harvard psychologist of education Jerome Bruner, works from the idea that the human mind is (habitually or by design) a pattern seeker, to more effectively engage students in learning by having them solve problems. See the following resources for additional information:

Bennett, B., & Rolheiser, C. (2001). *Beyond Monet: The artful science of instructional integration*. Toronto, ON: Bookation. (Chapters 8-9)

Bruner, J. (1966). *Toward a Theory of Instruction*. Cambridge, MA: Harvard University Press.

Bruner, J.S., Goodnow, J.J., & Austin, G.A. (1986). *A Study of Thinking*. New Brunswick, NJ: Transaction.

Deepen the inquiry into astrology by looking at documentaries (such as the video resources in the differentiated instruction section that follows), and then have students answer section question 1 on SE p. 328. Apply *scientific method*, as found in BLM 13.2 (column 1, "fits the rule"). Consider running the mini-debate in Chapter Review question 7, SE p. 339. This could be used to assess *as* learning students' preparedness for the larger debates to come.

DI Can students think of creative ways (perhaps initially using a Venn diagram—BLM A—but then moving beyond it) to show the differences between astrology and astronomy, also incorporating the ideas of science and non- or pseudo-science?

Look up the following video titles on the Internet (available for viewing on YouTube). These videos provide additional information on astrology and astronomy:

Astrology Debunked - Richard Dawkins in Enemies of Reason

Enemies of Reason Ep. 1 (1 of 5)

Carl Sagan on the pseudoscience of Astrology

Carl Sagan - Wonder & Skepticism 1

3. After reading about questions posed by the philosophy of science (SE pp. 318-320), undertake the group inquiry posed in the section question on SE p. 320. What kinds of philosophy of science questions can students come up with? As a catalyst for students to develop questions, look up the following video title on the Internet (available for viewing on YouTube):

   Philosophy of Science I

4. Before moving onto the historical review of science (SE p. 320), ask the class to produce evidence for Earth's spherical shape, perhaps challenging them with the trash can as an alternate model: the cylinder (which Xenophon actually proposed

in antiquity). With 11+ years of education, do they have anything more than pictures from NASA, which could have been fabricated, as in science-fiction movies, or the familiar globe that appeared in their elementary school classrooms? Were students indoctrinated into believing Earth is a sphere? See what they come up with, and then introduce the evidence marshalled by Aristotle (SE p. 321). Pythagoras and Plato had also taught that Earth is a sphere, and by the third century BCE, Eratosthenes was calculating the circumference of a spherical Earth within five percent accuracy. Use this history to build up to Teaching/Learning Strategy 2 in Teaching Plan 2, which is about the progression and regression of science, as Europe plunges back into a flat-Earth model until rediscovery of Greek and Persian astronomy after the Crusades, allowing Columbus to confidently sail west in search of India.

Acc Ask students to illustrate Eratosthenes' geometrical proof, using images available online:

http://media-3.web.britannica.com/eb-media/65/465-004-D1FFD8CD.gif

http://www.wired.com/images/article/full/2008/06/circumference_eratosthenes_500px.jpg

5. The student textbook section on the emergence of modern science in the Renaissance (SE pp. 322-324) is easily supplemented with documentaries on Galileo and Newton. Among the more interesting to come out recently is *Newton's Dark Secrets* (*NOVA*, PBS.org), on his experiments in alchemy and extensive writings on the Bible. An entirely different picture of the man emerges (e.g., a nervous breakdown?), along with insightful explanations of his laws of motions and scientific methods. The documentary also asks, "Is alchemy really a form of matter science?"

DI Offer students an opportunity to write about the development of scientific knowledge, using biographical and historical information to illustrate Kuhn's model of scientific revolutions (see SE pp. 332-333). They could base their write-up on, for instance, the movement from geocentrism to heliocentrism, or on successive models of gravity from Aristotle to Galileo and Newton, to Einstein and beyond. (See BLM 13.5.)

Additional resource:

Descartes's Secret Notebook: A True Tale of Mathematics, Mysticism, and the Quest to Understand the Universe, by Amir D. Aczel.

Also look up the following video titles on the Internet (available for viewing on YouTube):

Gravity - From Newton to Einstein - The Elegant Universe

Newtons Dark Secrets

The Science of Man: A Challenge to the Church - Age of Genius - BBC

Western Philosophy Documentary Section [2/3] part 1/5

6. Modern Science: Using BLM 13.4, conduct the activity where students piece together the scientific method (see SE p. 326, margin question). See also the question in Figure 13-2, SE p. 316: What makes the room depicted instantly recognizable as a science lab (applying the concept of *seeing as* from Chapters 11 and 12)?

Using the flowchart created in BLM 13.4, revisit the question of pseudo-science (see margin question on SE p. 325).

Acc For some students, science may not have been part of their studies since Grades 9 and 10. For additional background, look up the following video title on the Internet (available on YouTube):

The Scientific Method Made Easy

Text Answers

Page 320: Section question

Students develop their own questions, but may need some prompting. You could have students (or a group of them) develop an inductive learning list such as the one used in BLM 13.2, showing questions that follow the rule (i.e., conform with the philosophy of science) and those that break the rule (i.e., fall into science or into natural philosophy). Showing a segment of *Discovery* or *NOVA*, or another science program, or passing around back issues of a science magazine, could also help students find philosophical questions or aspects about science topics that generate philosophical questions. (See also Chapter Review question 5, SE p. 338.)

Page 324: Section questions

1. See SE pp. 37-38 for Bacon's "idols of the mind." People in the Renaissance were captivated by the *theatrical* model of geocentrism, taking it on authority and old lines of evidence, instead of open-mindedly evaluating new theories and evidence.
2. Consider an exploration of Leonardo da Vinci's investigations of anatomy and flight, both empirical inquiries based on direct observation and trial and error. Another example that is interesting to investigate is the relationship between Tycho Brahe and Johannes Kepler, Renaissance astronomers: the former more of an astrologer (with a silver nose) and the latter a mathematician and neo-Platonist (drawn to study the harmony of the spheres). Newton's Law of Gravity was influenced by Kepler's discovery of the three laws of planetary motion, the most significant being that a planet's average distance from the Sun cubed equals its orbital period squared—a proportional relationship that called for explanation, and which gravity delivers (the force of gravity is inversely proportional to the distance of the planet from the Sun).
3. Aristotle never got around to writing his books on oceanography and mineralogy, but we can excuse him as he did write so many others. The point is that people have to specialize, and increasingly so as the amount of information increases in every field. Science outgrew the relatively small domain captured by natural philosophy.

   We live in an era of specialization in which professors at academic conferences can scarcely comprehend the papers given within the many other, highly specialized subfields of their own discipline. In his novel *Immortality*, Czech novelist Milan Kundera describes Goethe's comprehension of the composite knowledge available in his day:

   > "In contrast [to us], Goethe lived during that brief span of history when the level of technology already gave life a certain measure of comfort but when an educated person could still understand all the devices he used. Goethe knew how and with what materials his house had been constructed, he knew why his oil lamp gave off light, he knew the principle of the telescope with which he and Bettina looked at Jupiter; and while he himself could not perform surgery, he was present at several operations, and when he was sick he could converse with the doctor in the vocabulary of an expert. The world of technical objects was completely open and intelligible to him."

Page 328: Section questions

1. The use of complex computations in astrology to chart the course of planets and stars (noting what house Venus is in, or which planet is transiting the Sun's path, for example) should not be confused with an exact science, where experiments are replicated under controlled conditions. There is nothing like verification or falsification to corroborate an astrological claim.

2. Rachel Carson's book *Silent Spring* heralded in the environmental movement, drawing attention to the health effects of spraying toxins (carcinogens) like DDT: birds, and ultimately humans suffer the consequences of such reckless use of poisons in the agriculture and forestry industries. Ironically, Carson died of cancer in 1964, just before DDT was banned in the United States. In 1991, Norway created the Rachel Carson Prize, in recognition of women who have made a strong contribution to environmental protection.

   Evelyn Fox Keller's first book, *A Feeling for the Organism: The Life and Work of Barbara McClintock*, was about a Nobel Prize-winning genetic scientist (1902–1992) who had to be given a PhD in botany because women could not major in genetics in her time. Reviewer Elizabeth Reninger (About.com Guide, January 25, 2009; http://taoism.about.com/b/2009/01/25/a-feeling-for-the-organism.htm) writes:

   > "Barbara McClintock was a maize geneticist, whose scientific insights were visionary - both in the sense of being 'ahead of her time' and in the more literal sense of being rooted in 'visions.' Similar to many other great scientists (e.g., Einstein) the key elements of Ms. McClintock's theories appeared to her in dreams. Thus received, her work from that point on was to translate this intuitive knowledge into a language which would allow it to be understood by the scientific community of which she was a part."

   Many feminist thinkers have agreed with McClintock that caring is integral to science. There must be a respect for the environment, along with a nurturing relationship for the environment to heal. It is this overarching goal that is not ordinarily felt in science.

3. Lyotard's depiction of science as a "grand narrative" dresses it down, much like Nietzsche's descriptions of history as parody (cited by Foucault). It lessens the age-old distinction between hard and soft sciences (e.g., physics versus psychology), as well as between the natural and social sciences. The scales here are set by relative degrees of certainty, or rational proofs and law-like theories. C.P. Snow's *The Two Cultures* also gives the impression of a great divide between the sciences and humanities, whereas Lyotard's reference to science as a narrative makes our explanations, like cosmology and evolution, something closer to the mythopoetic literature out of which philosophy first grew. In addressing Lyotard, the class may wish to revisit the question of epistemological relativism, from Chapter 11 (SE p. 287).

Teaching Plan 2 (SE pp. 328-339)

Activity Description

Small groups graph scientific progress as they understand it and then report their model to the class, using the board. Student groups then compare their model with Kuhn's, and compare it against several examples from the history of science (e.g., the Copernican Revolution).

Assessment Opportunities for Chapter Questions

The table that follows on the next page summarizes assessment opportunities for selected chapter questions, including questions in the Chapter Review, which are relevant to this teaching plan.

Learning Goal

Students will develop their own perspective on how science progresses, and come to understand Thomas Kuhn's model of paradigm shifts.

Assessment Type	Assessment Tool	Feature Questions	Section Questions	Chapter Review Questions
Assessment as Learning	Discussion; reflective writing	1-2, SE p. 335		
Assessment as Learning	Further research and application	1, SE p. 336		
Assessment for Learning	Charting and sorting schools (BLM C)		1-4, SE p. 337	
Assessment for Learning	Organizing and communicating knowledge			2-5, SE p. 338

Timing

225 minutes
(three 75-minute classes)

Learning Skills Focus

- Organization
- Initiative

Resources Needed

Make copies of this Blackline Master:

- BLM 13.5 Graphing Scientific Progress

Possible Assessment of Learning Task

As a way of encouraging students to read the chapter, tell them they will be asked to write two paragraphs in class (on their own, under test conditions), correctly and insightfully using 10 of the 16 terms listed on SE p. 316. They cannot just list the terms, but must demonstrate their comprehension through correct usage. (See also Chapter Review question 4, SE p. 338, which could be done for marks (count toward the final mark), or as a make-up assignment.)

Acc Allow students a chance to rewrite their two paragraphs, if at first they do not succeed. This brings everyone on board in terms of knowing the language of this unit, needed for the debates to follow in the culminating activity.

Assessment (For/As Learning)

As teachers move through each chapter, opportunities will be highlighted to provide assessment for/as learning in preparation for assessment of learning at the end of each chapter. See the table that follows for these assessment suggestions.

Task/Project	Achievement Chart Category	Type of Assessment	Assessment Tool	Peer/Self/ Teacher Assessment	Learning Skill	Student Textbook Page(s)	Blackline Master
Group reflection and reporting	Thinking	For	Figure 13-7, graphing scientific progress exercise	Peer	Collaboration	332	BLM 13.5
Applying Kuhn's model	Application; Knowledge	For	Class discussion	Peer; teacher	Independent work	332-333	
Venus case study	Application; Knowledge	For	Video resource, possible class reading, discussion, and questions	Teacher	Initiative	333	

Prior Learning Needed

The discussion here often draws on the history of science.

Teaching/Learning Strategies

1. Introduce the schools of thought in the philosophy of science by first addressing the metaphysical and epistemological topic of realism (SE p. 328). The recent

movement toward constructivism (the idea that we make up what counts as scientific knowledge) can be connected with the *linguistic turn* in philosophy, explained in Chapter 11, and also to Kuhn's historical paradigm shifts—different ways of seeing evidence and objects, through the lens of historically variant theories and concepts. (Recall the "*Treeness* of a Tree" feature in Chapter 11.) Positivism can be seen as an attempt to make our narrative more rational and less metaphysical, but it still requires assumptions about the existence of an external world we know indirectly through sense data. Look up the following video titles on the Internet to help you prepare (available on YouTube). You may want to show these videos in part to students:

Ayer on Logical Positivism: Section 1

Hilary Putnam on the Philosophy of Science: Section 1

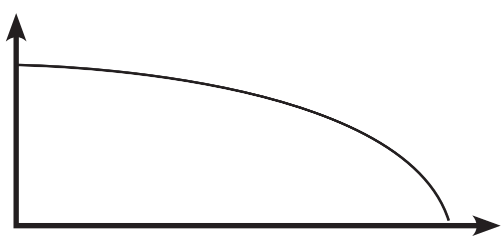
29. New Philosophies of Science

Acc The basic idea in positivism can be seen in attempts by ancient Stoic philosophers to rationalize the myths of old, such as finding evidence in Homer's *Odyssey* that he knew Earth was a sphere. Turning myth into a rational explanation of causation illustrates the concept behind positivism, which requires a more scientific explanation and the analysis of evidence instead of grandly eloquent theories.

DI See Chapter Review question 1, SE p. 338, for a variety of creative approaches to covering the schools of thought in the philosophy of science.

2. Using BLM 13.5, undertake the graphing activity outlined on SE p. 332, Figure 13-7. In Figure 13-7, students are asked, "Does the pattern have to go upward, from left to right?" Also ask students, "Does the pattern backtrack during times like the Dark Ages (return of the flat-Earth worldview)?

Ask students to consider the interesting case where knowledge goes down over time, as a proportion of the expanding potential for knowledge (i.e., our growing awareness of how much we don't know). A graph that shows such a curve might look like this:



DI Can the class think of more creative ways to show the progress of science, as in dance, sculpture, poetry, lyrics, collage (palimpsest), etc.?

3. The clearest example of paradigm shift that Kuhn provided was the Copernican Revolution. Ask students to assemble what they know about this major change of thought and test how well Kuhn's model applies to the Copernican Revolution. Then ask students to try to apply Kuhn's cycle of science to the shifts that occurred in the concept of gravity: moving from Aristotle to Newton, and from Newton to Einstein. (What about quantum theories of gravity?)

Kuhn was influenced by Wittgenstein, even in adopting the concept of paradigms. Make connections to Chapter 11, and the origins of constructivism in the twentieth century. Look up the following video titles on the Internet (available on YouTube). These video resources will help illustrate Kuhn's historical and sociological model of scientific progress:

One Minute Structure of Scientific Revolutions

The Structure of scientific revolutions pt1

Ask students: "Does Kuhn's model of paradigms generalize too much?" Encourage students who wish to follow up on this question to seek out Dudley Shapere's essay "Meaning and Scientific Change," in which Shapere suggests that it is a mistake to suppose that everyone within a tradition must share the same viewpoint, and that "unless there is absolute identity, there must be absolute difference."

Acc People use the term *paradigm shift* all the time, even to explain things like changes in education. Ask students: "Recalling the discussions of education in Chapter 12 (multiple intelligences theory, etc.), is there a paradigm shift happening in education now, or is it pretty much the same as it has always been?"

4. Illustrate the concept of *paradigm collision*, using the example of the *Magellan* probe data sent back from Venus. This data was subjected to differing interpretations based on the contrasting theories of planetary scientists. Look up the following video title on the Internet (available on YouTube). The video sheds light on this data and the different theories:

NOVA (PBS) - Venus Unveiled (1995)

The video (particularly starting at about minute 28) illustrates the shocking idea that the entire surface of Venus may melt down, submerging into the mantle every 500 million years! This is different than any other planet in the solar system. This information caused a paradigm collision among planetary scientists. If students are interested in reading the entire transcript of the NOVA video suggested above, it is available at:

http://www.pbs.org/wgbh/nova/transcripts/2210venus.html

If students watch the *NOVA* video or read the transcript, you may consider asking them to reflect on these questions:

a) How do the contrasting interpretations of the *Magellan* probe data reveal the *theory-ladenness of observation* in science?

b) How do the models—*uniformitarianism* and *catastrophism*—relate to the ongoing debate over gradual evolution versus sudden creation and recent disaster (e.g., the great deluge)?

c) Had you heard of Turcotte's theory prior to seeing this *NOVA* video? Has Turcotte's model gained wide acceptance today (as in being taught in Grade 9 Science classes or appearing on science programs other than this *NOVA* documentary)? Using Kuhn's stages of scientific revolution (Figure 13-8, SE p. 333), identify where the scientists in this controversial discussion appear to be at as Turcotte proposes his new model to skeptical planetary scientists.

To supplement the *Magellan* probe example of paradigm collision, consider using an excerpt from the novella *The Plato Papers* by Peter Ackroyd. In his book, Ackroyd writes about the discovery of an ancient text, which is in fact Darwin's *The Origin of Species* but is misinterpreted as a Dickens novel (i.e., it must be fiction). It creatively and humourously portrays a paradigm shift from *witspell* to *mouldwarp,* paralleling evolution and creationism.

5. The concept of *incommensurability* (SE p. 333)—that we lack a common measurement or standard from which we can even discuss a topic—raises deep questions of epistemological relativism, such as we encountered in the features of Chapters 11 and 12 (SE pp. 287 and 298, e.g., Afrocentric feminism). To make this less of an exotic encounter with African shamans and more of an encounter with an Oxford and Yale philosopher, consider showing to students Appiah talking on film. Look up the following video title on YouTube:

Kwame Anthony Appiah in Examined Life

For background, Peter Winch wrote a provocative essay in the 1980s on Asante witch doctors, drawing on Wittgenstein's perplexing remarks on the poverty of our scientific explanations when trying to persuade others into a way of seeing the world. It is not that Wittgenstein didn't believe in science; he had degrees in mechanical and aeronautical engineering. He is pointing back to how our knowledge rests on shallow bedrock, or how through acquisition of language and other cultural practices (including science instruction) we are initiated into seeing the world *this way* as opposed to another. In *On Certainty,* Wittgenstein writes:

> "Supposing we met people who did not regard that as a telling reason. Now, how do we imagine this? Instead of physics, they consult an oracle. (And for that we consider them primitive.) Is it wrong for them to consult an oracle and be guided by it? —If we call this 'wrong' aren't we using our language-game as a base from which to combat theirs?"
>
> "And are we right or wrong to combat it? Of course there are all sorts of slogans which will be used to support our proceedings."

Lyotard, of course, is building his postmodern reduction of science on his reading of Wittgenstein, as, in part, are Rorty and other neo-pragmatists like Putnam.

Text Answers

Page 335: Viewpoints

1. To address the question of efficacy in alternative medicine, revisit Appiah's statement in paragraph two, SE p. 334, on how we fail to see the reasonableness of some people's views or practices, because in assessing them we consciously or unconsciously apply our own as a standard of comparison. Many cases of folklore that might be ridiculed as non-scientific may indeed have empirical bases, or work in practice, even though we fail to see the evidence *as* evidence. Rooted in story and ritual, the medical knowledge of some cultures does not appear like Western medical knowledge, and may therefore be dismissed prematurely or unfairly as having no plausible basis in reality.
2. "Whose reality" invites the charge of relativism, which Appiah tries to sidestep in his discussion of culture on SE p. 335 (right column). If we are asking different questions and developing different narratives or articulations, we are not necessarily contradicting each other as much as passing each other by.

Page 336: Thought Experiment

Bayesian probability is used to assess and minimize risk, as in the insurance business. You can even get coverage for the remote chance that a piece of spacecraft will hit you here on Earth. Companies also use it to calculate the odds of a given piece of electronics going bad before the warranty period, and then sell extended warranty to cover a portion of the equipment's lifetime where it is still unlikely to break, hence putting the odds in favour of the company and not the purchaser. Most computer models in science incorporate probability to make plausible predictions based on various inputs, as in modelling climate change for forecasting our future carbon emissions based on present or increased rates.

Page 337: Section questions

1. Positivists are realists, whereas neo-pragmatists and Kuhn are constructivists. Saying they are constructivists, however, does not mean that they deny an external world; rather, in their view, it is impossible to escape our language to fully know any such external world, so we are always necessarily limited (our scientific knowledge made contingent) by our history and language.

2. Along with the pragmatists, students should be able to point to many things, such as technology, that we rely on all the time. Photosensitive doors open when we approach; elevators and airplanes take us up and down, mostly (but not always) safely. We are less sure of claims about the origins of the universe, as here the evidence is indirect, or it is input into a model or theory that explains what might have happened based on our current understanding of physics.

3. To explain how Kuhn's model of science builds upon Popper's, students may have to do some more research. One thing in common is the notion that seeing the evidence, or observation in science, is theory-laden. Another is the idea that science undergoes revolutions, though Kuhn emphasized more the conservative tendencies within normal science to prevent revolutions, to the point of denying anomalies or hiding evidence that is contrary to the standard model. The Novalis margin quote on SE p. 331 was from Popper's book *Objective Knowledge: An Evolutionary Approach*. See more on Popper and Kuhn in Chapter 14, SE pp. 353-355.

4. a) If we say a new paradigm has more descriptive and/or predictive capability, we seem to be saying it is *more true* than its predecessor. That appears to commit us to scientific realism, and to a view of gradual progress, or science as an accumulation of facts, instead of one narrative simply replacing another.

   b) The "Viewpoints" feature on Appiah and Asante practices (SE p. 334) is one example from the chapter where incommensurability comes into play. As another example, consider gravity as seen through different concepts: Aristotle's idea of gravity cannot be measured, so to speak, with the same metre stick as Newton's or Einstein's. Newton's concept of gravity, in his own time, was considered almost occult, as it posited a force operating without any particle or matter to carry it; today we can talk of gravitons in a way he could not, lending a material lens (wave-particle duality) to the problem.

Pages 338-339: Chapter Review

1. This activity suggestion provides teachers with a way of differentiating instruction.

2.

Key Philosopher	Concept	Strength	Weakness	Interesting
Ayer	verificationism	Familiar, realist notion	No actual way to ensure it	Allows progress over time
Popper	falsification	Helps us design experiments	Leads us to exclude even some appealing theories	Switches from inductive to deductive approach
Kuhn	paradigm shift	Shows human side or social aspects of scientific change	Can lead to relativism and misuse of incommensurability arguments	Connects with language and history, making science contingent upon these
Lyotard	grand narrative	Brings science down to Earth, and challenges long-standing assumptions; changes our picture of science	Leads to denigration of science and more extreme forms of relativism—an isles of language view, which Rorty criticized Lyotard of holding	Shows how our sciences are related to other narratives in our lives, and open to fabrication
Peirce, Dewey	fallibilism	Allows for skepticism in that we expect change, but also comfort in relying on what appears our best working explanation for now	Sidesteps the problem of truth by focusing on what we can assert now, with some warrant, instead of giving us eternal laws of nature	Focuses attention on what is useful, and stresses the need for open inquiry, or democracy and freedom of speech, for science to work

3. Calls for personal reflection, but also could be used as an assessment *for* or *of* learning. See the suggestion under the Possible Assessment of Learning Task in Teaching Plan 2.
4. This task—calling for argumentative or persuasive writing or speech—can be *scaffolded* by using graphic organizers (BLMs A or C), or by building the case through a mental mapping (BLM D).
5. This activity ties nicely into the section question on SE p. 320, asking students to develop their own related questions or topics. If carried out now, this activity allows for reflection after the chapter. It could also be postponed until the unit is finished.
6. This could be done first through *rites of passage* in life, such as birth, infancy, adolescence, etc. Next, how do we explain stages of human history, from nomadic to agricultural, to industrial society and beyond? Now revisit applications to science, perhaps drawing on Kuhn's book for examples.
7. This activity could be used to run a mini-debate, setting in motion the thinking students need to carry out the unit's culminating activity.
8. See references earlier in this chapter in Teaching Plan 1, Teaching Strategy 5.
9. Intended to generate divergent thinking, and perhaps encourage differentiated instruction, the final question moves us into the problematic genres of science fiction versus fictional science.
   a) For this question, it will help to revisit the correspondence theory of truth (SE p. 253).
   b) This question invites consideration of our escape into narratives we realize are fictional, but take comfort in inhabiting as fantasy scenarios. Does this also apply to some of our fondest theories, and does history help us realize this as we look back on what sometimes seem to be preposterous theories in the past?