BIG IDEAS

- Although induction is a crucial form of reasoning in the sciences, it is not without its problems, including its inability to account for itself through inductive reasoning. (SE pp. 342-347)
- Science and religion have often clashed throughout history, and for some may appear antithetical, but for many people they reinforce each other, revealing the secrets of creation. (SE pp. 348-352)
- Metaphysical and epistemological assumptions about scientific realism and constructivism form one basis for dividing schools of thought in the philosophy of science, as do differences between those who see science largely as an inductive or deductive enterprise. (SE pp. 353-359)

Chapter 14: Exploring the Philosophy of Science

Background

Use the discussion of substance in Chapter 4 (Spinoza, SE pp. 101-103) and theism and deism in relation to design in Chapter 6 (SE pp. 136-142) as background/connection to the discussion of science and religion in Chapter 14. Also use the "Philosophical Reasoning in Context" feature from Chapter 6 (SE p. 143), on false analogies in design arguments as background.

The later section in Chapter 14, on scientific realism and constructivism, may offer an opportunity to revisit the discussion of realism and nominalism in Chapter 11 (SE p. 285).

About Chapter 14

Divided into three major sections, this chapter explores the epistemological and metaphysical dimensions of the philosophy of science: the problem of induction as Hume initially understood it and as pragmatists later revised it; the boundary issues that arise as we bring religion and science into relation with one another; and the question of whether scientific theories and propositions mirror nature or reality, or more simply construct our best pictures and explanations at a given time.

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 below.

Feature	Student Textbook Page(s)	Opportunity for Assessment	Strategies for Classroom Use
Philosophers on Philosophy	356-357	1-3, SE p. 357, or a journal entry or research paper on Cartwright or Hacking. (See Chapter Review question 13, SE p. 361.)	Cartwright offers a clear illustration, saying she can model the physics involved in a bag of coins falling out a window, not a $1000 bill blowing around a plaza.
World Views Across Time	349-350	Further research, question box on SE p. 350. See also section question 4, SE p. 142 on scientific proof of God's existence.	Connecting the topic of religion and science to metaphysics (see above) will help initiate discussion, as will showing provocative video clips on Richard Dawkins and Francis Collins. The Scopes Trial and Dover Pennsylvania case (*NOVA* documentary) also animate this part of the unit.

Learning Goal

Students will gain a deeper appreciation of the role induction plays in scientific thinking, as well as awareness of its limitations. They will also better understand the metaphysical and epistemological problems associated with science and religion, and scientific realism and constructivism, as they expand their survey of schools of thought in the philosophy of science.

Teaching Plan 1 (SE pp. 340-352)

Activity Description

Hold a mini-debate on the question of teaching intelligent design versus evolution in public schools to increase student engagement and to practise the skills needed in the culminating activity debates.

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.

Assessment Type	Assessment Tool	Feature Questions	Section Questions	Chapter Review Questions
Assessment for Learning	Self or group reflection		1-3, SE p. 344	
Assessment as Learning	Group inquiry and discussion		1-3, SE p. 347	
Assessment for Learning	Self-directed research (extension activity)	SE p. 350		
Assessment as Learning	Self or group reflection		1-3, SE p. 352	
Assessment for Learning	Organizer chart; debate			2 and 7, SE p. 360
Assessment as Learning	Expository writing			4, 10, and 12, SE p. 360
Assessment as Learning	Poem, lyrics, poster, etc			9, SE p. 360

Resources Needed

Make copies of these Blackline Masters:

- BLM 14.1 Inductive Learning Using Problems of Induction
- BLM D Argument Builder

Possible Assessment of Learning Task

After watching parts of the *NOVA* documentary on Dover Pennsylvania, run the intelligent-design debate set out in Chapter Review question 7, SE p. 360. Use the debate rubric (see BLM 13.1 or BLM G) to assess student participation. If they do not succeed in this first debate, you might decide to use it as formative assessment *for* learning instead of assessment *of* learning, and provide critical feedback on how they can improve their skills for the culminating activity.

The film study (Teaching Plan 1, Teaching Strategy 2) could also be used as either assessment *for* or *of* learning.

Timing

300 minutes
(four 75-minute classes)

Learning Skills Focus

- Responsibility
- Collaboration
- Independent work
- Organization
- Self-regulation
- Initiative

(All learning skills are involved in the debate.)

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
Inductive learning/narrative writing exercise	Knowledge; Communication	For	Group activity to develop game (shared with others) and story telling	Peer	Collaboration	342-347	BLM 14.1
Agora film study	Thinking	For (or Of)	Further research	Teacher	Initiative; independent work		
Intelligent-design debate	Thinking	For (or Of)	Debate	Teacher	Initiative; collaboration	348-352	BLM D
Progress check	All	As	Learning-skills checklist and debate rubric	Teacher	Responsibility		BLM E

Prior Learning Needed

The same schools of thought that are addressed in this chapter also appear in Chapter 13, forming a basis for this chapter's discussion of induction.

Teaching/Learning Strategies

1. In small teams (2-4), ask students to use BLM 14.1 and try to devise an *inductive learning exercise* (similar to the one used in Chapter 13, BLM 13.2) that illustrates the differences between any two of the following: Hume's, Ayer's, Popper's, and Putnam's description (or definition) of the *problem of induction* (SE pp. 342-347).

This inductive exercise obliges students to read carefully and ascertain what criteria separate these different views of the problem of induction. *Game play*: Have students informally share their lists to see if others can figure out who their philosopher was (the one defined by the rule) and who they were distinguishing him from (the one that broke the rule). Then discuss the results, and note the difficulties students experienced. Use this as an opportunity to get students' questions into the open, and to clarify misconceptions they may have about the different schools of thought.

Next, ask student groups to turn their inductive learning exercise (their lists of statements) into a short *narrative account* that tells a story about a problem with induction. They could imagine they are conveying the problem to younger students from a Grade 9 class. They could even use the form of a fable, or a parable (as Franz Kafka often did), to convey the strange problems about something we take for granted every day: how we customarily rely on the repeated pattern of the Sun rising and setting. See, for instance, how Hume's *problem of induction* is turned back on himself, leading him to be unable to discover inductively a 'self' to narrate its own experiences (SE pp. 118-119).

Acc Some students might benefit from creating a *word wall* or their own glossary before attempting this exercise, as it assumes prior recognition of key concepts. Others might skip this activity and proceed to section question 1, SE p. 347.

Nelson Goodman's new riddle of induction: American philosopher Nelson Goodman (1906–1998) attempted to close the debate on the old problem of induction, arguing that Hume's problem has "withstood all attacks," and opened "new problems not as yet very widely understood." Encourage students who are interested in the problem of induction to research Nelson Goodman's new riddle of induction. Ask students, "How do Hume and Goodman differ in their approach to the problem of induction?" Then ask, "Should philosophers continue to work the problem of induction or is this a *dead end* in philosophy? Is an answer, perhaps, to come from neuroscience or cognitive science, or by 'dissolving' the problem through linguistic and logical analysis?"

DI Alternatively, students could depict or act out the problem of induction. Jerome Bruner, who initially promoted inductive learning as a way of recognizing a child's ability to make sense of his or her complex environment, later came to see the need for more holistic approaches, such as narrative methods that better convey the depth of background for understanding concepts (cf. discussion of background in Chapter 11, regarding Wittgenstein and Searle's epistemologies). Bruner's later cultural psychology is an example of social construction at work, where students are invited to make meaning and convey their sense of reality through discourse or story. In *The Culture of Education*, Bruner writes: "Our immediate experience, what happened yesterday or the day before, is framed in the same storied way. Even more striking, we represent our lives (to ourselves as well as to others) in the form of narrative."

Bruner was disenchanted with the so-called *cognitive revolution* that swept psychology into seeing the brain as hardware for running cognitive software (see Chapter 5, SE pp. 124-125 re: the Churchlands and eliminative materialism). Today, that computer modelling movement has resulted in something called Narrative Science®; software has actually been created to turn raw data into computer generated reports, with the hopes that one day a computer might win a Pulitzer Prize in journalism for composing stories we read in the daily papers. Could a computer have successfully turned their lists into a story? (Recall the "Thought Experiment" in Chapter 13, on the probability of a chimpanzee typing a masterpiece, SE p. 336.)

Additional resources on Narrative Science®:

http://www.narrativescience.com/

Lohr, S. (2011, September 10). In case you wondered, a real human wrote this column. *The New York Times*. Retrieved from http://www.nytimes.com/2011/09/11/business/computer-generated-articles-are-gaining-traction.html?pagewanted=all

2. Film study: Watch the movie *Agora* (2009), directed by Alejandro Amenabar and starring Rachel Weisz, and based on the life of Hypatia of Alexandria. (Note that this film contains scenes of nudity.) Hypatia (born C.E. 350–370; died March 415 C.E.) lived in Alexandria, Egypt, during the late Roman and early Christian period. She taught rationalist philosophy following the neo-Platonist tradition of Plotinus (third century C.E.), who, like Pythagoras, studied Persian, Indian, and Greek philosophy, and taught that the cosmos was filled with a divine intellect.

DI Ask students to write a short critique of the film (one to two pages) addressing the following questions:

a) Based on your research, how accurate was the portrayal of Hypatia: her thoughts and discoveries, and the problems of her times?
b) What metaphysical and epistemological theories or assumptions underlie Hypatia's natural philosophy?
c) Could Hypatia have anticipated the heliocentric theories of Renaissance astronomers—Copernicus, Kepler, and Galileo—without the use of telescopes? How did Aristarchus do so even earlier, in the third century BCE?
d) How does the movie portray the religious zealots, and what parallels are there today? What are examples of positive encounters between religion and science in the ancient world, or cases where religion guided scientific discovery?

To stimulate further research, students can look up the historical/archaeological video documentary about Hypatia on YouTube:

Hypatia and Alexandria [1/5]

The documentary, which employs excerpts of the Amenabar film (2009), positions the conflict between ancient science and religion. (The focus on Hypatia also sets up discussion of feminism in the philosophy of science in Chapter 15.)

3. After reading the "Thinking About Science, Religion, and Metaphysics" feature (SE pp. 349-350), encourage students to explore the links to other cultures and times (see feature question on SE p. 350). Then launch into the modern debate on religion and science. Look up the video titles about Dawkins and Collins that follow (available on YouTube) to help establish the basis for the debate set out in Chapter Review question 7 (SE p. 360).

The God Delusion Debate - Richard Dawkins vs John Lennox (preview)

Richard Dawkins -- The God Delusion

God Strikes Back (3/5) - Richard Dawkins

Richard Dawkins Enemies of Reason

The Veritas Forum: The Language of God (Francis Collins)

Richard Dawkins & Daniel Dennett vs. Francis Collins & Benjamin Carson - Science and Faith

Acc Hand out BLM D before showing students the videos listed above to encourage them to think of who and what they use in their own arguments, though they should take notes before actually filling in the template on the BLM.

Then show students the beginning of the *NOVA* video on Dover, Pennsylvania (look up video title suggested below, which is in several parts) to stimulate the debate suggested for Chapter Review question 7 (SE p. 360). Students can use BLM D to organize their arguments in preparation for the debate, and then form teams. Also see BLM 13.1 for suggestions on running the debates and for the assessment criteria.

NOVA | Intelligent design on trial 1 - 12

Debate the resolution: Biology texts in high-school science courses *should* include intelligent design along with evolution. (Or reverse it: ...*should not*...)

Look up the following video titles on YouTube to use as supplementary resources:

Stephen Hawking: Physics Leaves No Room For God

Can Intelligent Design be Falsified?

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

Age of Genius: Life and times of Scottish philosopher David Hume - Explore - BBC

4. Conduct a progress check on culminating activity preparations: Refresh the instructions for students from BLM 13.1, and ensure team formation is complete and note-taking/argument formation toward the final debates is under way. Consider using BLM E Learning Skills Checklist to track students' progress.

Text Answers

Page 344: Section questions

1. The key term for Hume is *habit* or *custom*, as induction is seen as something we develop and rely upon, much as we do other practices, even if we cannot account for it by means of induction itself.

2. Descartes appears to assume we have a God-given ability to fathom the causes of things, as God created the world in such a way that we can know it through reason. Descartes' thinking on causation can, at times, be muddled, as a result of his separation of mind and body, or thinking and extended substances (see SE pp. 101 and 115).

   Kant considered causation to be one of the *a priori* concepts we bring to experience—such as space and time, motion and solidity—as the mind rationally organizes or coordinates empirical observations. (See Unit 4, SE pp. 255 and 271.)

   Students may wish to explore Descartes' ideas more thoroughly in relation to the views of Princess Elisabeth of Bohemia. Students can refer to the book *The Correspondence between Princess Elisabeth of Bohemia and René Descartes,* edited and translated by Lisa Shapiro. (Excerpts from this text are available at Google Books.) Book description: "Between the years 1643 and 1649, Princess Elisabeth of Bohemia (1618–1680) and René Descartes (1596–1650) exchanged fifty-eight letters—thirty-two from Descartes and twenty-six from Elisabeth. Their correspondence contains the only known extant philosophical writings by Elisabeth, revealing her mastery of metaphysics, analytic geometry, and moral philosophy, as well as her keen interest in natural philosophy."

Students can also find excerpts of this correspondence in the book *Voices of Wisdom. A Multicultural Philosophy Reader*, by Gary E. Kessler.

3. If a pet returns to the same location every morning to inspect its food dish, it is using induction. But does it make further inferences, as humans would, about the shopping cycle that brings in the bag of food, and the pay schedule upon which shopping relies? Humans take induction to a higher level, perhaps, just as we do in terms of anticipating the thoughts and actions of others: something in primate studies called the *concept of mind*, where we can take our meta-level cognition about the mental states and intentions of others to as high as five times removed from our own, and we can also maintain a larger number of social contacts than our nearest cousins in the animal world. See *The Human Spark* (*NOVA*, PBS) with Alan Alda on this fascinating difference between us and chimpanzees. Philosophers like Peter Singer question whether we are falling into *speciesism* when we exalt ourselves above other species.

Page 347: Section questions

1. The following table may be of help in checking student summaries on the problem of induction:

Philosopher	Problems identified with induction
David Hume	Induction cannot be used to account for itself, creating the need to assume it is a habit or custom humans develop and rely on for empirical knowledge.
Alfred Ayer	Because induction itself requires an inductive ground, the problem of induction is insoluble (viciously circular). That needn't stop us from using induction, however, so long as we can make reliable predictions using induction.
Karl Popper	We can never verify an hypothesis, as the positivists claimed, because tomorrow our predictions may fail (e.g., swans will be black, or the Sun may not rise). We can only set up test conditions that falsify or corroborate our hypotheses, and in so doing demarcate science from non-science (i.e., what is untestable). What this means is that scientists are concerned with setting up experiments and choosing methods that could potentially test an hypothesis, and not with matters that do not allow for any means of falsification.
Hilary Putnam	From a pragmatic angle, that we cannot justify induction presents no serious problem in that we successfully use induction all the time in our daily lives.
Nelson Goodman	As suggested earlier, students who wish to examine the problem of induction further can research Goodman's "new riddle of induction." Goodman attempts to close the problem of induction by suggesting that the problem of justifying induction has been displaced by the problem of defining confirmation. He suggests that our work upon induction has left us with the residual problem of distinguishing between confirmable and non-confirmable hypotheses. One might say roughly that the first question was "Why does a positive instance of a hypothesis give any grounds for predicting further instances?"; that the newer question was "What is a positive instance of a hypothesis?"; and that the crucial remaining question is "What hypotheses are confirmed by their positive instances?"

2. As students prepare their interpretation of Popper's attack on verification, they may want to look up Popper's book *The Logic of Scientific Discovery* on Google Books. Direct students to two consecutive paragraphs in Popper's book that begin with "Now in my view there is no such thing as induction." As well, direct students to the first paragraph of Chapter 2 of Popper's book. That paragraph begins thus: "In accordance with my proposal made above... ."

3. See Units 2 and 4 regarding neuroscientific approaches in philosophy (e.g., the Churchlands) and Chapter 12 (Ryle, SE p. 301) regarding analytic philosophy (based on Hume's Fork, the analysis of words, discussed in Chapter 10, SE p. 254). Again, students who wish to research and examine Goodman's new riddle of induction will find that Goodman suggests that the problem of justifying induction has been displaced by the problem of defining confirmation. Students will find many descrip-

tions of the new riddle of induction on the Internet. They will also find excerpts from Goodman's book *Fact, Fiction, and Forecast* at Google Books. (After students find Goodman's book at Google Books, suggest that they look at the table of contents to find the chapter on the new riddle of induction.)

Page 350: World Views Across Time

Science is possibly a different enterprise for monotheistic, pantheistic, and polytheistic thinkers because depending on one's metaphysical views on substance and matter, they may see the subject of their scientific enquiries as an investigation of God, or of the divine creation and/or plan. Materialist-oriented scientists in the former Soviet Union often explored areas of parapsychology that Western scientists might be reticent to touch, looking for physical relationships instead of spiritual explanations. An Indian yogi, for instance, was asked to astral-project (teleport) his consciousness into a black box on the space station *Mir* (Peace) to see if he could determine what was inside: an experiment one would not likely find on the American-led International Space Station.

Page 352: Section questions

1. The question calls for a personal response. Ayer and Dawkins may present a challenge to, or disappoint, some students who are religiously inclined.
2. Like Spinoza, Armstrong seeks to overcome a mind-body dualism, as is found in the thinking of Descartes. The view of the Creator among Aboriginal peoples, though possibly influenced by contact with Christian missionaries, goes against the views of Spinoza, however, as he does not envision a supreme being who attends to the affairs of people or of the world. Communication with animals is also something quite outside the philosophical worldview of Spinoza; in his time (seventeenth century) it would likely have been considered a Pagan idea, drawing suspicion of witchcraft (e.g., familiarity with cats). It is perhaps best to understand Armstrong's appeal as an invitation to a new, healthier environmental ethic. Subjecting her views to scrutiny on the basis of Western science sets up the kind of problems Appiah addressed in Chapter 13 (SE p. 334), discussing the Asante worldview.
3. This question calls for some research into French philosopher Pierre Duhem (1861–1916), and serious consideration of how a devout Catholic could reconcile his religion with science, and how, on a cosmic scale, religion may play a role that science cannot fill on its own. Whether students agree or disagree, they should respond to Duhem's ideas by drawing on the ideas of philosophers of science and metaphysics.

Learning Goal

Students obtain a deeper appreciation of the problems of scientific realism and constructivism, questioning what a scientific theory is and whether it mirrors nature.

Teaching Plan 2 (SE pp. 353-361)

Activity Description

Charting the similarities and differences in thinkers on the question of scientific realism, students come to a better understanding of key thinkers in the philosophy of science. They also try creative methods of showing the perplexing ideas encountered in the feature on Cartwright and Hacking (SE pp. 356-357).

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	Feature Questions	Section Questions	Chapter Review Questions
Assessment for Learning	Self-reflection and note taking	1-3, SE p. 357		
Assessment for Learning	Comparison charts; various media (film, poster, PowerPoint, etc.); prose response		1-4, SE p. 359	
Assessment as Learning	Self-reflection and note taking			1, 3, 6, 8, and 13, SE pp. 360-361
Assessment as Learning	Poem or lyrics, drawing/illustration, etc.			9 and 13, SE p. 361
Assessment for Learning	Expository writing			4, 5, and 11, SE pp. 360-361

Resources Needed

Make copies of these Blackline Masters:

- BLM 14.2 Chapter 14 Vocabulary Quiz: Matching
- BLM C Comparison Chart

Timing

150 minutes
(two 75-minute classes)

Learning Skills Focus

- Independent work
- Organization

Possible Assessment of Learning Task

Use BLM 14.2 to quiz students on Chapter 14 terminology (see SE p. 316 for key terms).

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
Vocabulary quiz	Knowledge	For (or Of)	Matching quiz	Self; teacher	Independent work	316	BLM 14.2
Creative representation	Thinking; Communication	As (or Of)	Collage or other creative interpretation	Peer; teacher	Independent work; initiative	361, questions 9 and 13	
Compare and contrast thinkers	Knowledge	For	Use the comparison chart to organize notes on Toulmin, Popper, and Kuhn; and on Cartwright and Hacking	Self	Independent work	353-357	BLM C

Prior Learning Needed

See nominalism versus realism in Chapter 11, SE p. 285.

Teaching/Learning Strategies

1. Ask the class to interpret the margin quote by Robert Pirsig (SE p. 353) on ghosts. How are scientific theories like or dislike ghosts? How does the analogy help us to understand the problem of scientific realism? How does the earlier discussion of nominalism and realism in Chapter 11 relate to this discussion (see SE p. 285)? Then ask students to use a graphic organizer (such as BLM C) to collect notes on how Toulmin, Popper,

and Kuhn referred to theories. What is the reason for the tension between Kuhn and Popper (look ahead to Chapter 15, SE p. 374 to help answer this question)?

2. Tell students that at the end of the chapter there will be a vocabulary quiz to see who is following the key terms from the opening of the chapter (SE p. 316). The terminology will be needed in the upcoming culminating activity debates. See BLM 14.2 for the Chapter 14 vocabulary quiz.

   Acc Consider another version of the quiz for students who are having difficulty with the vocabulary. Perhaps prepare a short-answer version of the quiz instead of a matching format (some of the phrasing of the vocabulary quiz may be more difficult for ELL and Special Education students).

3. Check on students' progress in their preparation for the culminating activity debates, possibly tracking their learning skills with BLM E and showing them the targets for success in the rubric shown on BLM 13.1.

4. To help students get a grasp of who Ian Hacking is (one of Canada's most prominent philosophers), show them the first 10-15 minutes of his keynote speech (the title of the video is listed below and is available for viewing on the Internet). Hacking's speech demonstrates how an essay can be set up in its introduction, which will be useful to students for later culminating activities.

   Proof, Truth, Hands, and Mind with Ian Hacking

   Hacking uses a mixture of Wittgenstein and Foucault in his work *Historical Ontology*. Revisit Chapter 11 for discussion of these twentieth-century philosophers.

   DI Similar to the collage shown in Figure 14-1, on SE p. 340, ask students to create a collage to represent Cartwright's idea of *metaphysical nomological pluralism* (SE p. 357; see also Chapter Review question 9, with Figure 14-7, and question 13, SE p. 361).

Text Answers

Page 357: Philosophers on Philosophy

1. By the term *fundamentalism*, Cartwright means a view of the world and science where laws and theories give us a firm foundation for knowledge about reality itself. See the concept of *post-foundationalism* in Chapter 11 (SE p. 275), on which Cartwright draws. Her alternative to fundamentalism is a patchwork of local theories instead of grand, universal laws of nature. It provides enough bedrock to stand on, without actually being a firm or permanent foundation for knowledge in science (see SE p. 282).

2. Hacking's term *robust fit* applies to Cartwright's approach to scientific theory and reality in that she, too, recognizes that, on a local scale at least, we do sometimes get it right and produce useful technology. The fact that electrons can be sprayed (Hacking's example, used by Cartwright) means they cannot be entirely socially constructed. In his book *The Social Construction of What?*, Hacking comments on how nobody is a social constructionist at 30 000 feet (i.e., while in an airplane). Yet he, like Foucault, adopts a nominalist view in that he focuses on how we change the names and theories for things as we move through history, resulting in different discourses that create "spaces of possibility for things" (i.e., what they can be, seen from a historical ontological or linguistic-metaphysical framework). Plutonium, for instance, is something humans created, hence it is in dynamic interplay between what Hacking calls *dynamic realism* and *historical nominalism*.

3. Cartwright's position of *nomological pluralism* may have the negative consequence that we become skeptics or relativists, always doubting the ability of science to arrive at anything definitive. Would scientists working at the Hadron Supercollider continue their search for a grand unified theory (of the four forces of nature), if they doubted its universality or objectivity? Strong counterexamples might be things like hydrogen bombs, which suggest we do know how the Sun works through fusion reactions. Recall that Oppenheimer originally worked on stellar evolution (e.g., supernova explosions), before creating the atomic bomb.

Page 359: Section questions

1. Both Toulmin and Cartwright are drawing on Ludwig Wittgenstein for their philosophies of science. There is a similarity between Toulmin's notion that theories operate like general rules, which are sometimes broken in practice, and Cartwright's idea that we only get things right at the local scale. Both offer reservations on generalization, which Wittgenstein admonished his students to beware of (including Toulmin, who also became one of his biographers).

2. Hacking explains in *The Social Construction of What?* that "Constructionism about the natural sciences is also, in part, a metaphysical position. It is directed at certain pictures of reality, truth, discovery, and necessity. It joins hands very naturally with what Nelson Goodman calls irrealism: not realism, not anti-realism, but an indifference to such questions, which in itself is a metaphysical stance." He goes on to write that although constructionism can go hand in hand with an enthusiasm for science, it is more often used to expose an ideology of science, unmaking its claims to pure reasons that are intended to generate pious reverence toward science. "It must be said, as a purely anecdotal generalization, that every single constructionist about the natural sciences whom I know well is thoroughly irreverent." In this sense, Hacking credits Goodman and others with fuelling the so-called *science wars* of the 1980s and early 1990s: "The science wars, as I see them, combine irreverent metaphysics and the rage against reason, on the one side, and scientific metaphysics, and Enlightenment faith in reason, on the other." Hacking tries to stand outside and chronicle this war, in which Goodman was embroiled (as was Kuhn).

3. Both thinkers have a realist orientation when talking about theories fitting the facts of reality or nature, as in Popper's concept of *verisimilitude* (SE p. 354). Where Popper denounced the positivist idea of *verification*, Kuhn is still willing to use the term in an evolutionary sense of better models replacing weaker ones (SE p. 355). Kuhn is seen as the more constructionist thinker, as scientists work together to socially produce and propagate scientific paradigms or models, sometimes regardless of their ability to accommodate all of the facts at our disposal (evidence that gets overlooked by those defending the normal science or dominant theories of their day).

4. Paul Feyerabend was not exalting in religious fundamentalism, which he is antithetical towards as an anarchist, but trying instead to defend society from its own tendency to put science up on a pedestal, as reason incarnate, instead of questioning its claims, methods, sovereignty, or exclusivity, and right to public funding. Science, in other words, runs the risk of becoming like medieval religion, doctrinaire instead of critical, and totalitarian instead of liberating. Science in the former Soviet Union was often the failed model Popper and Feyerabend pointed to, though this did not spare the West from similar criticism.

Pages 360-361: Chapter Review

1. Hilary Putnam once remarked that realism "is the only philosophy that doesn't make the success of science a miracle." It is easier to assume that the human mind is capable of arriving at facts about an external reality, resulting in theories that are true. Realists see our best theories as at least approximating the truth about a mind-independent world, in so far as they allow us to make reasonably accurate empirical predictions (e.g., comets returning) or successful applications (e.g., aerodynamics).

2. See the chart on the problem of induction under section question 1, SE p. 347 (above, Teaching Plan 1). Students could add their own columns to that chart to identify strengths, weaknesses, and ideas of interest.

   On the boundary between religion and science:

Thinker	Something positive	Something negative	Something interesting
Hume	He was an advocate for empirical science, helping science move beyond its metaphysical trappings in natural philosophy and theology.	Leaves no room for God. He'd burn books on religion and metaphysics.	His nephew had to publish Hume's ideas after Hume's death, as Adam Smith recommended he withhold them to escape persecution.
Duhem	Combines physics and theology when viewed on the grand scale.	Could be seen to have been socialized into French Catholicism, and therefore could have easily been brought up Hindu or Buddhist elsewhere.	"In philosophy of science, he is best known for his work on the relation between theory and experiment, arguing that hypotheses are not straightforwardly refuted by experiment and that there are no crucial experiments in science." http://plato.stanford.edu/entries/duhem/
Dawkins	A strong proponent of rational thinking in opposition to dogmatism.	Leaves no room for spiritualism, and comes across as being as dogmatic in his defence of science as some others are of religion.	Draws on evolutionary theory to explain how we came to hold religious views (i.e., the so-called *God gene* in us that creates awe and reverence for a supreme being or parent figure).
Collins	Finds a way to reconcile his religion (Christianity) with his genetic science.	In coming to religion later in life, is he seeking comfort before his death?	Rides a motorcycle. Heads up the Human Genome Project, which offers compelling support of the Darwinian theory of evolution.

3. The difficulty here is that certainty about the existence of things, such as atoms and photons, falls under metaphysical realism, or belief in the reality of an external world we can come to know. Being anti-realist about theories means they are aware of how theories are constructed at moments in history where the theory is contingent on the language and culture of the times. Together, these discursively open up a limited range of possibilities for what can be regarded as true, or declared a fact at a specific juncture in history. The example of theories on conception in Chapter 15 (SE p. 382) reveal what Hacking would see as the *nominalist* as opposed to realist basis of theories, as does the ancient Chinese taxonomy quoted by Foucault (Hacking's central philosopher) on SE p. 285.

4. Pierre Teilhard de Chardin was a Catholic theologian, famous for presenting the idea that humanity forms the evolving consciousness or *noosphere* (*nous* is Greek for mind): a layer of collective thought on our planet, much as air and water comprise the atmosphere and hydrosphere (see SE p. 14, Figure I-10). He was a visionary more than a scientist, but very inspirational to many.

5. To answer this question, students could revisit the activity set out in BLM 13.5, and Figure 13-7 (SE p. 332).

6. We could ask the pragmatic (fallibilist) question: If it is ultimately impossible to judge a scientific claim *as true*, then how would we move on in science or add to our inventory of technologies? The semantics are important, as this takes us back to Wittgenstein in Chapter 11, where we count some things *as true* (or as stable bedrock for now) within our current language-games, knowing full well that they may be replaced later. See which theories students have the most affinity with, perhaps using the Chapter 14 vocabulary terms that are identified in the question in their own writing.

7. This debate can help students develop their skills for the culminating activity debates. This debate could also be used for assessment purposes.

8. Having more than one correct scientific theory at a time may appear to violate the laws of thought set out at the beginning of the course (non-contradiction, excluded middle, etc.), but it is quite possible that two groups working independently of each other would arrive at divergent theories, both of which might explain successfully the evidence available with the given apparatus or scientific equipment of the day. It is also possible that both theories might be supplanted later by a new and better theory, which accounts for the anomalies more comprehensively and benefits from new and more powerful equipment (or more open conditions of inquiry). If hypotheses are infinite, then it does not seem like they are doing their work as nets or filters in capturing or sorting data. There usually appears to be a finite number of solutions to any problem, and fewer for the harder problems.

9. The creative activities here could be done as assessment activities—*as, for,* or *of* learning.

10. Students will make the application of induction to their own life and science studies, and compare their results. If they expect an allowance, or an upcoming unit test, they are using induction to make the inference. In labs, they often draw conclusions based on repeated attempts or procedures, as in missing chemicals and watching the reaction, several times to confirm the anticipated (hypothesized) result.

11. a) German philosopher Carl G. Hempel (1905–1997) explored questions of induction, explanation, and rationality in science, building upon the earlier work of logical positivists like Rudolf Carnap and Hans Reichenbach (1930s–1940s). At one point in his career, Hempel was famous for creating what he called a *deductive-nomological* model of science.

    What is known as Hempel's Paradox takes us back into the question: How do we make a valid generalization, based on repeated observation? Seeing black ravens repeatedly, we are reasonably inclined to conclude that "All ravens are black." So, for example, the next time someone is talking about a raven, you have good reason to believe the bird in question is black.

    Implicit in this inductive expectation is the notion that each sighting of a black raven adds evidence or validity. Hempel's Paradox disturbs this confidence by showing what it logically entails: If we say that (1) "All ravens are black," then, by implication, it is logically equivalent to say (2) "Everything *not* black is not a raven." Logic is like *set theory*: in this case, we can exclude everything not black from the set to which ravens belong. If you're confused, try drawing a Venn diagram to picture the relationships. Logically, if (1) is true, then so is (2), and vice versa. Naturally, whenever we find another black raven, the additional evidence supports our first statement. Oddly, however, so must finding anything *not* black and *not* a raven—such as the red car in our crash scene (Figure 14.2)—add evidence for statement (2). Furthermore, since the statements are logically equivalent, finding anything *not* black and *not* a raven adds evidence for statement (1). In terms of inductive probability, if finding another black raven

adds to the probability that statement (1) is true, then, by equivalency, so does finding the red car add to the probability of statements (1) and (2) being correct.

Popper's answer to the question would be to shift emphasis from verifying the inductive generalization, "All ravens are black," to establishing instead a test for this deductive hypothesis and then see whether it is *falsifiable*. The conditional hypothesis, "All ravens are black," is apparently acceptable because: (a) it is *testable* in that one could sample raven populations to determine that they are all black, and the experiment is repeatable in that other populations could also be sampled at different times and places; and (b) it is *falsifiable*, because a single non-black raven would disprove the hypothesis. If all of the ravens found are indeed black, then the hypothesis is supported by evidence and deemed plausible (though not fully *verified*, in the earlier positivist terminology).

One cannot really sample every raven population in the world, however, and it may turn out that rare, albino ravens are seldom found because they are more susceptible to predation and thus short-lived. Sampling may not result in seeing a white raven, even though they in fact exist. This presents a problem, in that the original hypothesis may not be *falsifiable* after all. Mutation can lead to a rare white specimen, and natural selection sometimes results in populations of animals changing colour over time. It might in fact be the case in the future that "Most ravens are white," and that the person was referring to a white bird.

Pragmatists Israel Scheffler and Nelson Goodman took up the problem along similar lines, incorporating Popper's view that scientific hypotheses are never really confirmed—only falsified. On their account, observation of a black raven does not prove that "All ravens are black," but rather falsifies the contrary hypothesis, "No ravens are black." Put another way, seeing another black raven *selectively confirms* that "All ravens are black" but not that "All non-black things are non-ravens." As the authors put it in their paper "Selective Confirmation and the Ravens: A Reply to Foster":

> "... the statement that all ravens are black is not merely *satisfied* by evidence of a black raven but is *favored* by such evidence, since a black raven disconfirms the contrary statement that all ravens are not black, i.e. satisfies its denial. A black raven, in other words, satisfies the hypothesis *that all ravens are black rather than not:* it thus selectively confirms *that all ravens are black*."

Scheffler and Goodman's concept of *selective confirmation* is an example of an interpretation of "provides evidence in favor of" that does not coincide with "increase the probability of." In this way, they avoid the paradox that seeing any non-black thing, such as a red car, adds to the probability that "everything not black is not a raven," and by equivalency, that "All ravens are black." Although logically equivalent propositions, *selective confirmation* does not apply in the case of sighting any non-black item, as it does not disconfirm the hypothesis that "No ravens are black."

b) Goodman's pragmatist response to Hempel's Paradox—that seeing another black raven selectively confirms that "All ravens are black" but not that "All non-black things are non-ravens"—shifts the focus back onto what we do by our inductive habits or practices instead of tying us up in a logical knot of induction, which does not appear to present any problem in real life. However, Goodman's "new riddle of induction" (alluded to earlier) seems equally obtuse, introducing the 'gruesome' prospect of blue-green emeralds (called *grue*) instead of the familiar green emeralds we anticipate seeing on the basis of induction.

See also SE pp. 32-35 regarding abductive arguments.

12. It could be said that Western science is a way of seeing and modelling the world, different from the ways in which religion sees and models the world. Armstrong used this sense of the term *paradigm shift* in her appeal for transformation in the way we see the environment (SE p. 352).

13. a) A quilt, instead of a hierarchical structure such as a pyramid, suggests we piece together our provisional understandings as a way of getting by, instead of the most elegant theory we could imagine.

b) Imagine a cartoon in which scientific laws try to command objects. It creates a picture rather like *Alice in Wonderland*.

c) Here is a vicious circle from which we cannot escape, like a whirlpool swirling.