

Thanks for using *Two-Fisted Science* in your classroom. The following are some ideas for generating discussion, critical thinking, and further learning based on what your students just read.

Content questions

Full Circle (Galileo)

How good do you think Galileo's telescope was? [Answer: Not very: much less powerful than a typical pair of today's bird-watching binoculars.]

Follow-up: He was still able to make many important discoveries like the moons of Jupiter and the phases of Venus. How did he do that?

Galileo was right about the planets moving around the sun. Why do you think he got in trouble anyway?

Shoulders of Giants (Newton & Leibniz)

Do you think Newton and Leibniz ever met? In a bar? Why or why not?

We use Leibniz's notation for calculation rather than Newton's? Why do you think that we do that, even though Newton is more famous?

Safecracker ("A Very Good Scheme," "Either You Open It or You Don't," "Tickling the Dragon's Tail")

Does Richard Feynman fit your mental image of what a scientist should be like?

Do you have any skills that people wouldn't expect from you?

Why doesn't Feynman always open the safes he's asked to as fast as he can?

What is "tickling the dragon's tail"? Do you think anyone would do this experiment today?

Would Feynman really have tried to get into Building Omega without permission?

Feynman Lectures on Physics

What's going on here? Why doesn't Feynman get hit in the head? (What if he had moved?)

Arline

Do you find Feynman's argument for staying with and then marrying Arline persuasive?

Who is Feynman writing his letter to? Why?

CERN

Have you ever gone on a trip with someone who was sure they knew the way, and didn't?

CERN is really big, and straddles the border of France and Switzerland. Can you find it on a map? [Hint: It's right at the tip of Lake Geneva.]

Most of the Good Stuff

Even when he was dying of cancer, Richard Feynman continued to discover new things. For example, he helped figure out why the first major space shuttle (Challenger) accident happened. Can you find out what he did? [Dipped an o-ring into a glass of ice water during a televised hearing, dramatically showing how cold could affect the seals they formed around the fuel lines.]

Russell Lectures on Cosmology

Do you think Bertrand Russell convinced the woman?

What is your favorite myth about how the world works? Why do you like it/ why is it such a good story?

Heavy Water

Werner Heisenberg is a controversial figure to many scientists. Why?

Do you agree with Bohr when he says that the military use of science is inevitable? Justifiable?

General

What chapter or story do you find most effective? Why? Be as specific as you can.

How would you describe the tone of the book as a whole? Cite specific pages and/or panels as examples.

Which character do you find most memorable? Why? Be as specific as you can.

Which characters do you find to be the most interesting and engaging? That may be different than most memorable! Why? [Which character would you like to go on a vacation with? Which character(s) would you want to invite over for dinner?]

How would you describe Bernie Mireault's artistic style? What is its most striking feature? How do you compare it to Steve Lieber's style?

Choose a page in the book and carefully examine how the writer and artist combine words and pictures in effective ways.

What point do you think is being made on pages 125-126?

Before reading this book, what were your attitudes about these scientists? In what ways has the book changed your mind about these places and people?

If you could ask the artist(s) any questions, what would they be?

If you could ask the writer any questions, what would they be?

Storytelling questions

Why do you think "The Shoulders of Giants" was done in that particular way? Why is this not realistic?

Why do you think page 78-79 are done that way? Why are the characters positioned the way they are? Why does the last panel have no border?

On page 69, what happened between panels 3 and 4 (and 4 and 5, and...)? What happened between page 70 and 71?

Pay close attention to backgrounds throughout these stories. How do the writer and artist establish and treat setting and environment?

Why did the book start with Pauli's story, and end with Bethe's?

Why do you think the art looks the way it does in the Galileo story? Would you have liked it better if it was more "realistic"? If so, why?

Ask the characters! Ask yourself!

Now that you've read the book, try answering some questions as if you were one of the characters. Then, pretend like you were in the character's situation. How would you answer it for yourself?

"Professor Feynman, why did you work on the Manhattan Project?"

"Newton, why didn't you and Leibniz get along?"

"Professor Bethe, do you agree with what your wife said? Are there limits to what science can show us?"

"Galileo, why did you publish your last book, even though your friend the Pope told you not to?"

Vocabulary

lens

telescope

orbit

Aristotle

calculus

möbius strip

ensorhip

CERN

heavy water

quantum physics

uncertainty principle

cloud chamber

fission

More to explore

Books

Galileo's Daughter, by Dava Sobel, (NY: Walker & Company, 1999). If you read one book on Galileo, please make it this one. It brings him to life like no other.

Men of Mathematics, by E.T. Bell, (NY: Dover, 1937). An extremely engaging book. Bell is in turns gossipy and informative and entertaining, especially where Newton's and Leibniz' lives are concerned.

The Nature and Growth of Mathematics, by Edna E. Kramer, (Princeton, NJ: Princeton University Press, 1970). The intellectual history of math, including calculus and the paths Newton and Leibniz used to get to it.

The Character of Physical Law, (Cambridge, MA: The M.I.T. Press, 1965). Beautiful lectures on why the world works.

QED, (Princeton, NJ: Princeton University Press, 1985). The best popular physics book I've read. It makes you think you understand Feynman's Nobel Prize winning work almost as well as he did.

"Surely you're joking, Mr. Feynman!", as told to Ralph Leighton, (NY: W.W. Norton, 1985). The book that made Feynman into a pop culture icon. Every story he tells entertains, and a few even enlighten.

"What do you care what other people think?", as told to Ralph Leighton, (NY: W.W. Norton, 1988). This provided the basic narrative for "Arline". It also covers Feynman's last public adventure, the Challenger inquiry. Almost as good as *"Surely you're joking..."*.

Tuva or Bust!, by Ralph Leighton, (NY: W.W. Norton, 1991). Ralph Leighton did the "as told to" honors for the books listed above, and along with Michelle Feynman he also gave his kind permission to adapt many of the stories you've just read.

No Ordinary Genius, by Christopher Sykes, (NY: William Norton & Company, 1994). Tom Van Sant's CERN story appears in this well-illustrated book in which many famous people offer their perspectives on Feynman and tell their Feynman stories.

A Brief History of Time, by Stephen Hawking, (NY: Bantam, 1988), relates the turtle story, whose premise is much older. East Indian and Chinese mythology both have turtles standing in for the Greeks' Atlas, and Native American cosmology tells the story of Sky Woman: After she had fallen from a hole in the sky, three animals try to find earth under the waters to give her a place to rest, but only the turtle succeeds. Present day Iroquois call earth "Turtle Island".

What Little I Remember, by Otto Frisch (London: Cambridge University Press, 1979) is a great book through and through, and is the source of the dragon's tail story.

Uncertainty, by David C. Cassidy, (NY: W.H. Freeman, 1991). This book gives an in-depth biography of Heisenberg.

The Making of the Atomic Bomb, by Richard Rhodes, (NY: Simon and Schuster, 1986). You'll have a hard time finding a better book about the subject than this. Not only is it meticulously researched, it reads like a well-plotted novel.

Niels Bohr: A Centenary Volume, edited by A.P. French and P.J. Kennedy, (Cambridge, MA: Harvard University Press, 1985). A beautiful book, covering many facets of this famous man.

Heisenberg's War: The Secret History of the German Bomb, by Thomas Powers, (NY: Alfred A. Knopf, 1993). More on Heisenberg's WWII experience, or as much as we can infer from the many conflicting accounts he, and others, gave.

Spoken Word

"Surely you're joking, Mr. Feynman!", by Richard Feynman, as told to Ralph Leighton, (NY: W.W. Norton, 1985) and *Safecracker Suite*, sound recording by Ralph Leighton, 1988.

Safecracker Suite, sound recording by Ralph Leighton, 1988. A CD of Feynman playing drums and telling the safecracker story to Ralph Leighton. 69 minutes and 45 seconds of fun.