Einstein's Messengers and National Science Standards

Two sets of K-12 National Science Standards have influenced the development of state standards across the U.S. over the last decade.

Project 2061, sponsored by AAAS, has published Science for All Americans (**SFAA**), a book that "outlines what all students should know and be able to do by the time they leave high school." A companion 2061 book, Benchmarks for Science Literacy (**BSL**), identifies specific benchmarks for increasing science understanding in grade levels K-2, 3-5, 6-8, and 9-12. Benchmarks provides a tool for helping educators design curricula that will meet the objectives of SFAA.

The *National Research Council (NRC)*, under the auspices of the National Academy of Sciences, published the National Science Education Standards (**NSES**) in 1995. The NRC standards "spell out a vision of science education that will make scientific literacy for all a reality in the 21st century. They point toward a destination and provide a roadmap for how to get there."

♦ Science for All Americans
AAAS, Project 2061
Oxford University Press, October 1990
ISBN: 0195067711

♦ Benchmarks for Science Literacy
AAAS, Project 2061
Oxford University Press, Jan 1994
ISBN: 0195089863

♦ National Science Education Standards
National Research Council
National Academy Press, 1995
ISBN: 03090523269

The table below lists themes of "Einstein's Messengers" that relate to science standards which appear in SFAA, BSL and NSES. The column on the right lists outcomes related to the themes and standards that students could accrue from watching and discussing the film.

Standards-related themes in the film	Learner outcomes related to themes
Science ideas change over time	Recognize that important scientific ideas can change
Einstein's model of gravity, general relativity	Contrast Einstein's model of gravity with Newton's
Wave behavior	Recognize the similarity between gravitational waves and other types of waves
The role of technology	Recognize that interferometers are new tools in the search for gravitational waves
Models are scientific tools	Recognize that computers are essential in constructing models of star collisions and similar events
Sociology of Science	Describe the size of the LIGO project in terms of numbers of scientists, engineers and students involved
Human values in science	Describe the role of curiosity in the advancement of science

Here are possible questions that teachers could use in conjunction with the film. The second set contains open-ended questions that could be used for additional student writing and/or for class discussion.

Film Questions

- True or false: Humans have held basically the same idea of gravity for hundreds of years. Explain your choice.
- Describe Newton's concept of gravity. How did Einstein's ideas about gravity differ from Newton's?
- Describe a difference and a similarity between gravitational waves and water waves.
- What's the name of the instrument that LIGO uses to detect gravitational waves? Draw a simple diagram of one of these instruments
- Why is technology important in LIGO? In your opinion, is LIGO a science project, an engineering project or both? Explain your choice.
- The movie shows a number of computer simulations (models) of events that happen in space. How will scientists decide if these models are accurate?
- How many people work on LIGO, roughly speaking? Why might such a large number of people be necessary?
- Why is it important for a scientist to be curious?

Extension Questions

- Many people think they know what a 'typical' scientist looks like (white lab coat, thick glasses, funny hair, etc.). Do you think that the LIGO scientists in the film fit this description? What, in your opinion, would be some important characteristics of scientists if not their appearance? What makes a scientist a scientist?
- Imagine that you are working for LIGO and you and your fellow scientists think that you've finally detected gravitational waves directly. No one has ever done this before. What would you do to build confidence in your result? How would you answer those who might say "No, the signal you measured was probably a truck driving by, or an airplane flying overhead, or a small earthquake"?
- LIGO scientists work at institutions all over the world. Would you enjoy working with a group of hundreds of people that are spread out all over the place? What would be some of the challenges of working with a group this large? What would be some of the potential benefits?
- LIGO's quest to measure gravitational waves is an example of basic science research. Basic research projects are designed to question, discover and explore nature's fundamental behaviors. Do you feel that basic science projects such as LIGO are important? Is there value in learning about the universe? Share your thoughts.

Science education content standards facilitate science literacy by identifying essential science content and key intellectual processes. The identification of essential content creates an aura of emphasis on the status quo. Several of the gravity standards, for instance, use Newtonian language rather than relativistic language. "Einstein's Messengers" can act as a valuable counterpoint and supplement to standards-based teaching by highlighting the pioneering and "outside-the-box" nature of basic research. Standards are inherently tidy, while research is often by turns messy and foggy but also exciting. The film gives teachers and students a glimpse of the pioneer aspect of basic science.

SFAA = Science for All Americans
BSL = Benchmarks for Science Literacy
NSES = National Science Ed. Standards

Description of Film Scene	**Connections between Film Exposition and Science Standards**	**Relevant Standards**	**Source of Standard**
2:40 – Comparison of Newton's gravity to Einstein's	. . gravitational waves . . . they're not anything like the gravity you thought you knew , , . . . Newton defined gravity . . the force that pulls the apple down. . . . Gravity, he said, isn't the attraction of objects like planets. It's a distortion of space and time. . . . space is not a simple flat arena in which matter and energy play around . . . It's not that there's a force between them . . its that they're falling into each others' holes . . . . . it led Einstein to a prediction, that when two stars . . collide, they produce waves – gravity waves	*Scientific Ideas are Subject to Change* ("Change in knowledge is inevitable because new ideas may challenge prevailing theories")	SFAA , Ch. 1, The Nature of Science, p2
		The Scientific World View ("No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising and occasional discarding of theories, new and old, never ends")	BSL Ch. 1, The Nature of Science, p8
		Forces of Nature ("Everything in the universe exerts gravitational forces on everything else, although the effects are readily noticeable only when at least one very large mass is involved")	SFAA , Ch. 4, The Physical Setting, p55
		Forces ("Gravitational force is an attraction between two masses. The strength of the force is proportional to the masses and weakens rapidly with increasing distance between them.")	BSL , Ch. 4, The Physical Setting, p96
		Relating Matter & Energy and Time & Space (". . . Einstein published what is regarded as his crowning achievement and one of the most profound accomplishments of the human mind in all of history: the theory of general relativity. The theory has to do with the relationship between gravity and time and space, in which Newton's gravitational force is interpreted as a distortion of the geometry of space and time")	SFAA , Ch. 10, Historical Perspectives, p151
		Relating Matter & Energy and Time & Space ("General relativity pictures Newton's gravitational force as a distortion of space and time.")	BSL Ch. 10, Historical Perspectives, p245
		Motions and Forces ("Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of	NSES , Ch. 6, Content Standards (Physical Science),

		the distance between them")	p180
4:30, 5:58, 7:00 Wave Behavior	Like ripples on a pond, these waves travel outward from their source, carrying information about the events that caused them, racing at the speed of light . . . . . . the universe is totally transparent to gravity waves . . . . just as waves on the surface of a pond get weaker and weaker the farther they propagate, so do gravitational waves . . . . . . this is what happens to space itself [when a gravity wave passes]. .it stretches in one direction and compresses in another . . .	I*nteractions of Matter and Energy* ("Waves, including sound and seismic waves, waves on water and light waves, have energy and can transfer energy when they interact with matter.	NSES , Ch. 6, Content Standards (Physical Science), p180
		Motion ("Vibrations may set up a traveling disturbance that spreads away from its source . . . We therefore speak of sound waves, light waves and so on . . .")	SFAA , Ch. 4, The Physical Setting, p53
		Motion ("Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.")	BSL , Ch. 4, The Physical Setting, p90
0:35, 1:50, 10:30,18:20 Technology	..some mysteries so deep that the answer cannot be found with traditional tools. For those it takes	*Technology Draws on Science and Contributes to It* (". . . science often suggests new kinds of behavior that had not even been imagined before, and so leads us to new technologies.")	SFAA , Ch. 2, The Nature of Technology, p26

	. . . History has shown that great discoveries in science usually occur when revolutionary new instruments give us new ways to explore the universe		
5:10, 21:00, 21:30 Models	. . .As scientists tried to simulate these waves, they found that they can be immensely powerful . . . . . . “ . . combined with numerical simulations I expect will revolutionize our understanding of general relativity . . .”	*Models* (“A models may be a device, a plan, a drawing, an equation, a computer program or even just a mental image. Whether models are physical, mathematical, or conceptual, their value lies in suggesting how things either do work or might work.”)	SFAA , Ch. 11, Common Themes, p. 168
		Models (“Computers have greatly improved the power and use of mathematical models by performing computations that are very long, very complicated, or repetitive. . . The graphic capabilities of computers make them useful . . . in the simulation of complicated processes	BSL , Ch. 11, Common Themes, p270
9:05, 10:50 Complex Social Activity	. . . “ . . Oh, but the payoff is enormous, and that’s what keeps you really motivated. . “ . . . LIGO is the work of hundreds of scientists, engineers, and students . . .	*Science is a Complex Social Activity* (“They (scientists) may work alone, in small groups or as members of large teams.”)	SFAA , Ch. 1, The Nature of Science, p7
		Science as a Human Endeavor (“Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding.	NSES, Ch. 6, Content Standards (History and Nature of Science), p200

1:40, 18:20 Curiosity	. . . Rai Weiss has been dreaming of this moment for decades . . . . . . there’s a moment of wonder there . . . . . they are people who never lost their childlike wonder about the universe	*Reinforcement of General Societal Values* (“*Curiosity*. Scientists thrive on curiosity – and so do children. “)	SFAA , Ch. 12, Habits of Mind, p185
		Values and Attitudes (“Know why curiosity, honesty, openness and skepticism are so highly regarded in science and how they are incorporated into the way science is carries out . . .”)	BSL , Ch. 11, Habits of Mind, p287