GLOSSARY

Activity—a system of human actions, interactions, and transactions whereby a subject (a person, team, or machine) works on an object (e.g., material object or problem-space) in order to obtain a desired outcome. In order to do this, the subject employs tools, which may be external (e.g., books, computers, equipment) or internal (e.g., concepts, plans, algorithms).

Being|becoming—this notation is inspired by Anna Stetsenko's model of human development where becoming (or being) is the process by which individuals come to understand and transform the world and themselves by contributing to the world. In other words, changing one's world, knowing one's world, and being (or becoming) oneself are all part of a single continuous process. It is not possible to separate the lifelong process of human development into discrete stages or periods of knowing, being, and transformation. We use a "Scheffer stroke" (|) to indicate that being and becoming exist in a dialectic. That is, one always presupposes the other—we are always being and we are always becoming, and we cannot "be" unless we've "become," and we cannot "become" unless we "are."

Career scientist—refers to a person who earns a living wage by conducting scientific research. A career scientist might work for a colleague or university, a government department (e.g., Department of Environmental Protection, Institute for Educational Sciences), a science-rich cultural institution (e.g., museum, aquarium, or park), a for-profit company (e.g., pharmaceutical company, oil company), or a not-for-profit organization (e.g., World Wildlife Fund).

Collaborative transformative practice—refers to the practices people engage in when changing one's world, knowing it, and being (or becoming) oneself in view of their goals. These practices always involve contribution because self-development and community development are types of contributions. Collaborative transformation practice refers to the endless, interconnected, and dynamic processes of being and becoming, knowing and learning, and transforming and changing oneself and one's environment (e.g., Stetsenko and Arievitch, 2004).

Contribution—the meaning of contribution is a standard dictionary meaning, "anything given or furnished to a common stock, or towards bringing about a common result" (OED, 2014a). The emphasis here is on the fact that "people always *do* contribute to something that goes on in the world, even if only on a small scale, and even if by doing nothing (because the latter type of a 'contribution' often helps to perpetuate the existing status quo and to stifle changes in society)" (Stetsenko & Arievitch, 2004, p. 495). Teachers contribute to the world by creating safe and inviting environments where students can learn about the world and contribute to the world. Through these actions of teaching and learning, children and teachers change the world and themselves as part of the world.

Discipline perspective—refers to the organization of science as well as the expectations for learning particular facts, skills, and norms relevant to the scientific enterprise. The discipline perspective typically represents science as a three-part structure, including the (1) body of knowledge in science, (2) methods and processes of generating knowledge in science, and (3) ways of knowing in science—or Nature of Science (NOS) and students are expected to learn canonical knowledge and practices in each of these areas.

Everyday tools—also referred to as everyday concepts or spontaneous concepts. Everyday tools refer to concepts (rules, norms, information, skills, etc.) that are based on intuitions and everyday experience (Bodrova & Leong, p. 210). They are the result of the generalization and internalization of everyday personal experience in the absence of systematic instruction (Karpov & Haywood 1998, p. 28).

Human activity—see *Activity*.

Knowledge-acts—instead of using the word *knowledge* or *knowing* to refer to the state of possessing facts and skills in our brains, we propose using the term *knowledge-acts*. This captures the reality that knowing and knowledge are shorthand for the action or the ability to take action with a particular tool for thinking or learning to pose, define, or solve a problem or do intellectual work (e.g., knowing means we can prove it, show it, explain it, make predictions) By thinking about *acts* of knowledge instead of *facts* of knowledge, the human activity is constantly made visible, that is, the actions of using tools for thinking to "collaboratively transform the past in view of the present conditions and future goals." Knowledge-acts and tools for thinking are interdependent. Actions require tools for thinking, and tools for thinking arise from and are transmitted through action.

Learner perspective—refers to the questions and goals of science learners. It presumes the learner is interested in the world around her and is eager for ways to learn how to learn more about it. A learner perspective embodies the spirit of wonder and the desire to understand and explain, emotional-psychological states which are necessary to sustain scientific inquiry. In our interpretation of a learner perspective we recognize that the goals of any science learner are to learn how to enter the conversation of science now and in the future, conduct inquiry in the pursuit of credible information, and be|become a scientist. The phrase *a learner perspective* does not refer to observations or ideas about students' particular interests or opinions (e.g., "Many students this age get excited about dinosaurs and outer space"; "Bella is really interested in how weather forecasting works"; "Aiden has been collecting rocks and wants to know how volcanoes work").

Learner–scientist—refers to anyone interested in science, including but not limited to students (e.g., K-12, college/university students), teachers, science teacher educators, citizen scientists, and career scientists.

Learning action—refers to "the actions students use to solve learning tasks. Examples of learning actions include framing the problem, general and specific strategies of solving the problem, monitoring, evaluating the results, and self-correction" (Bodrova & Leong, p. 210).

Object—in activity theory, the object refers to the problem-space or physical material on which the subject works. For example, a science object might be understanding how people are affecting the Earth's resources, finding the cause of an infectious disease, or explaining the difference between inherited and acquired characteristics. (*See* object–motive.)

Object–motive—in activity theory, the subject (e.g., a student or teacher) works on an object, and this makes the object the motive of the activity. Usually motive is thought of as separate from the object. For example, we often refer to internal and external "motivators," such as: students are motivated to learn by an engaging book or teacher, or they are motivated to please themselves or others. These portrayals disregard the notion that the motive is embedded in the selection of object. In other words, the object (e.g., understanding how people are impacting the Earth's resources) is what motivates the activity. For example, if "pleasing others" is an actual motive for learning about the Earth's resources, then the object of the activity is to please others by understanding how people are affecting the Earth's resources. In activity theory, a motive is an object, material, or ideal that satisfies a need.

The Scientific Method—this refers to a common myth perpetuated in school science and science for the public. It is perpetuated by a variety of people, including science educators, career scientists, science teacher educators, science journalists, and science textbook authors. There is no single scientific method used by scientists. A variety of methods and processes are used in science to answer questions and test assumptions and hypotheses. Methods are fluid and dynamic guidelines that can never be repeated the same way twice by the same person or between people.

Theoretical tools—also referred to as scientific concepts. Theoretical tools refer to concepts (rules, norms, information, skills, etc.) reveal essential patterns, principles, and relationships that represent the generalization of the experience of humankind and that children are taught in the course of systematic instruction. Once scientific concepts have been acquired and internalized by learners, they can be used to mediate student's problem solving. (Karpov & Haywood, 1998, p. 28)

Tools for thinking—instead of using the word *knowledge* to refer to an object such as information, explanations, facts, ideas, laws, concepts, theories, schema, rules, norms, social practices, skills, and algorithms, we propose the using phrase *tools for thinking*. This is based on the work of the educational psychologist Lev Vygotsky, who explained higher mental functions (e.g., mediated perception, focused attention, deliberate memory, and logical thinking) are performed using tools and signs generated by people to accomplish these functions. Tools for thinking are dependent on knowledge-acts and vice versa.

APPENDICES

APPENDIX A

Transcription Conventions

Although conversation analysis was not performed in this study, excerpts were transcribed following adaptations of the conventions of the "Jefferson system" (ten Have, 1999, pp. 213–214).

Sequencing

=	An equals sign shows "latching," that is, two utterances are not separated by a detectable pause.

Characteristics of speech production

—	A dash denotes a sharp cut-off of a prior word or sound.
.	A period indicates a natural ending and a stopping fall in tone.
,	A comma indicates a comma-like pause. It indicates continuing intonation such as when one reads items from a list.
?	A question mark indicates a rising intonation

Transcriber's doubts and comments

((*text*))	Descriptions enclosed in brackets contain transcriber's descriptions in addition to transcriptions.
[*text*]	Transcriber's assumption about a spoken word or phrase
text	Text formatted in italic highlights utterances discussed in the interpretation

APPENDIX B

Interview Protocol: For a study of the meaning of the word scientist

Interviewer: There are no right answers. We are trying to learn more about people's perceptions of scientists. It's really important to say what *you* think.

1. This is one definition of *scientist* we found in the Oxford English Dictionary:

   "A person who conducts scientific research or investigation; an expert in or student of science, especially one or more of the natural or physical sciences".
   Do you agree with this definition? Why or why not?

2. Can you think of anything to add or anything you'd like to change about the definition?

3. How are you like a scientist?

4. If you don't think of yourself as a scientist, why not?

5. What do you think scientists do that you don't do?

6. A career scientist is someone who earns a living or salary as a scientist. I have three questions to ask you about career scientists.
   a. Who do you think can be a career scientist? Why?

   b. Who do you think cannot be a career scientist? Why not?

   c. Do you think career scientists are similar or different from non-career scientists? Why or why not?

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APPENDIX C

Media Analysis Guide: How the authors of the science books and magazines in my/our library represent scientists (*can be used for any media source type*).

Book Title: ____
Book Author: ________________________ Publication Date: ___________
Research Associate: ____________________ Analysis Date: ______________

Indicators	*No examples*	*A Few examples*	*Many examples*
No scientist, fictional or real			
Anonymous scientist (“the scientist … ” or “scientists say … ”)			
Real scientist with a name			
Fictional scientist character is a person			
Fictional scientist character is an animal			
Female children (fictional or real)			
Female adults (fictional or real)			
Female children as scientists (fictional or real)			
Female adults as scientists (fictional or real)			
Male children (fictional or real)			
Male adults (fictional or real)			
Male children as scientists (fictional or real)			
Male adults as scientists (fictional or real)			
White (Europe; Middle-East)			
Black, African American, Caribbean American			
American Indian or Alaska Native			
Asian (China, Cambodia, India, Japan, Korea, Malaysia, Pakistan, Philippines, Thailand, Vietnam)			
Other ethnic identity			
Working in a laboratory			
Working outdoors			
Working alone			
Working with one other person			
Working with a group			

Additional Comments

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APPENDIX D

Interview Protocol: A study of the science experiences of our elders

Interviewer: Some research with students our age shows that when we draw pictures of scientists we usually draw white men in lab coats working in indoor laboratories. We are studying whether or not our elders (our parents, grandparents, aunts and/or uncles) have ever experienced discrimination that might make them think they were not good at science or that science wasn't for them. Would you talk to me about your experiences in school science? [*If the RA you ask agrees to an interview, then ask the following questions.*]

1. What to you remember of elementary school science?

2. Did you like elementary school science?

3. Could you describe any adult scientists (fictional or real) featured in TV, books, or films you enjoyed?

4. Could you describe any child/youth scientists (fictional or real) featured in TV, books, or films you enjoyed?

5. Did you every think you were not good at science?

6. Did you ever think science wasn't for you?

7. Did anyone ever tell you that you couldn't be a scientist?

Other reflections:

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APPENDIX E

A digest of the educational background of each author on the Next Generation Science Standards writing team as described on the *nextgenscience.org* website. Refer to the individual biographical sketches on the website for more detailed information about awards and additional positions held by each author.

Primary employment	*Educational background*	*Surname*
Elementary teachers	Elementary Science Resource Teacher, Washington DC BS—Elementary Education, Bemidji State University MS—Curriculum and Instruction, Mankato State University	Hommeyer
	Elementary Teacher, Willowbrook, Illinois BA—Biology, University of Illinois-Chicago MS—Elementary Education, Northern Illinois University	Januszyk
	Elementary teacher, Washington, DC BA—not listed MA—Reading Certification—STEM Education, Teachers College Columbia University	Jones
	English as a Second Language and Bilingual Resource Teacher, Madison, WI BS—Curriculum and Instruction and Spanish, University of Wisconsin, Madison MS—Bilingual Studies, University of Wisconsin, Madison Certifications—ESL and Bilingual Teaching	Miller, E.
	Elementary Science Specialist, Hallsville, MO BS—Special Education, Illinois State University MA—Science Education (in progress) National Board Certification—Early Adolescence Science	O'Day
	Elementary Math and Science Teacher and STEM Coordinator, Bowie, MD BS—Biology, South Carolina State University MA—Curriculum and Instruction (Science and Technology concentration), Loyola University	Smalls
Middle school teachers	Earth Science Teacher, Moorhead, MN BS—Geology, Allegheny College MA—Geology, University Tennessee Certification—UT-Knoxville	Colson

(Continued)

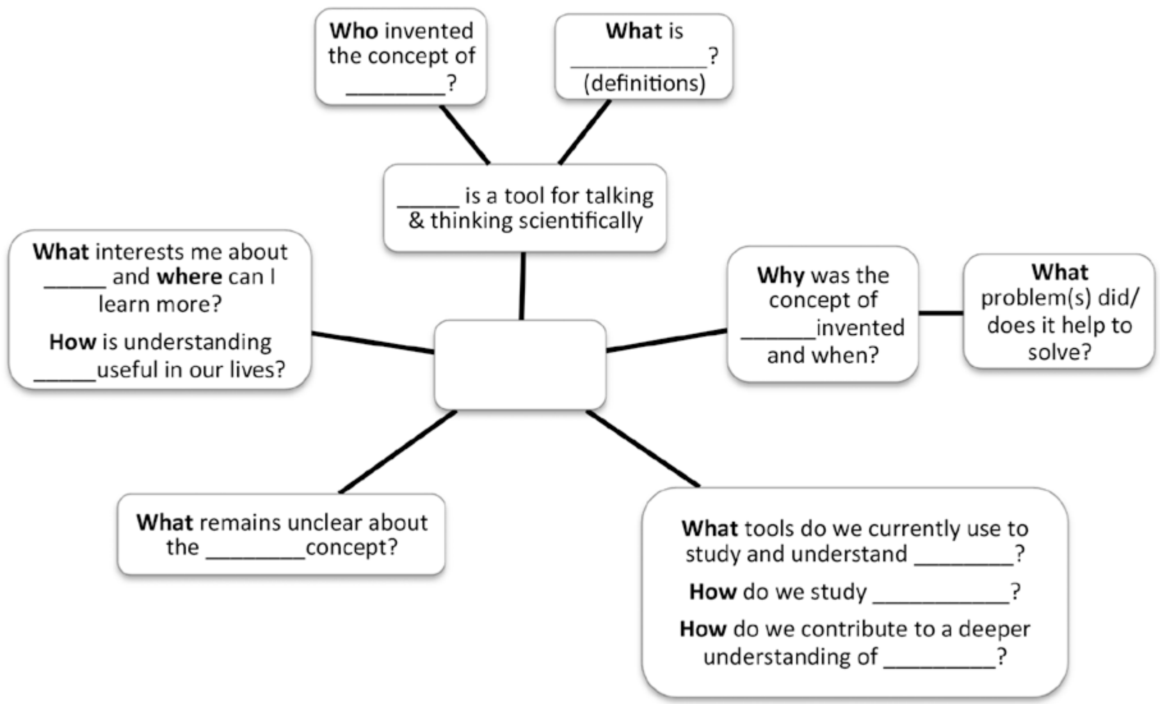
Primary employment	Educational background	Surname
	Middle School Science Teacher, Williamsville, NY BS/MS—Education, State University of New York at Buffalo	Huff
	Middle School Science Teacher, Farmington, AR BS—Elementary Education, Arkansas Tech University National Board Certification—Early Adolescence Science	Miller, M.
	Mentor Teacher and Science Standards Trainer, Maryville, TN BA—Education, University of New Orleans MA—Educational Administration, University of New Orleans	Pepperman
	Middle School Science Teacher, Rogers, AR BS/MS-Education, University of Arkansas	Prophet
High school teachers (some with additional research experience in industry)	High School Science Teacher, Stanford, IL BA—Animal Science and Agricultural Education, University of Illinois MS—Agricultural Education, University of Illinois	Mohr
	High School Science Teacher, Washington, DC BS—Chemical Engineering, Drexel University MA—Producing Film and Video, American University MA—Teaching, American University	Okoro
	High School Science Teacher, Mitchell, SD BS—Biology, University of South Dakota MA—Biology, University of South Dakota	Olson
	High School Science Teacher (retired), New York, NY BS/MA—Science Education, City College of New York	Speranza
School/State Administrators/ Coordinators (all with classroom teaching experience)	Science and Music Curriculum Director, Orland Park, IL BS—Physics, Loyola University PhD/ED—Educational Leadership, National-Louis University Certification—6-12 Education, Loyola University	Baker
	Assistant Principal, Carrollton, GA BA—Middle Grades Education, University of West Georgia MA—Middle Grades Science, University of West Georgia Certification—Educational Leadership, University of West Georgia	Evans

Primary employment	*Educational background*	*Surname*
	District Program Manager for secondary science (retired), San Diego, CA BA—Zoology, Pomona College PhD—Zoology, University of California-Berkeley Certification—Teaching, University of San Diego	Ezell
	Secondary Science Coordinator, Flower Mound, TX BA—Zoology, Texas Tech MA—Physiology, Texas Tech	Fisher
	Director of Science and Technology/Engineering, Massachusetts Department of Elementary and Secondary Education, Malden, MA BA—Earth Science, Hampshire College MA/PhD—Science Education, University of Michigan	Foster
	Regional Science Coordinator, Olympia, WA BS—Physical Science, Washington State University MS—Science Education, Oregon State University PhD—Science and Math Education, Curtin University	Gabler
	Science Curriculum Specialist, Chandler, AZ BS—Journalism, Northern Arizona University MA—Elementary Education Arizona State University Certification—K-8 teaching, Northern Arizona University; Administration, Arizona State University	Gutierrez
	Science Coordinator, Katy, TX BA—Elementary Education, Sam Houston State University MA—Early Childhood Education, Kennesaw State University	Herrington
	High School Science Teacher and District Science Coordinator, Harrisburg, VA BS—Physics, James Madison University	Jackson
	Science and Technology Specialist, Rhode Island Department of Education, Providence, RI BA—(not listed) MA—Science Education, University of Rhode Island	McLaren
	P-SELL and STEM Coordinator, Orlando, FL BS—Early Childhood Education, University of Central Florida MA—Education (in progress) Certifications—Gifted Education, Reading Education, and ESOL education	Milano

Primary employment	*Educational background*	*Surname*
	Director, Utah Partnership for Effective Science Teaching and Learning, Ogden, UT BA—Chemistry (major), Biology, Math and Physics (minors), University of Utah MA—Education, Weber State University Certification—Administrative Supervision, Utah State University	Moulding
	Professional Development Facilitator, Spanish Fork, UT BS—Elementary Education, Brigham Young University MA—Teaching and Learning, Brigham Young University Certifications—Administrative Supervision; Gifted and Talented Education; ESL; Mathematics; Reading	Paulson
	Science Education Consultant, Forks, WA BS—Zoology, University of Washington MA—Curriculum and Instruction, Lesley University Certification—Secondary Science	Schaaf
Career Scientists (with college science teaching experience and science education research experience)	Professor of Physics, Arlington, TX BA—Physics, University of Illinois at Urbana-Champaign MA—Space Physics, Rice University PhD—Space Physics, Rice University	Lopez
	Associate Professor of Earth and Planetary Sciences, St. Louis, MO BS—Geophysics, Brown University PhD—Geophysics, Northwestern University	Wysession
Career Science Education Researchers (most with classroom teaching experience)	Executive Director, BSCS (Retired) BA—(not listed), University of Northern Colorado MA—(major not listed), University of Northern Colorado PhD—Science Education, New York University	Bybee
	Lappan Phillips Professor of Science Education and Professor of Chemistry, East Lansing, MI BS, MS, PhD—Chemistry, University of Manchester, England	Cooper
	Waterbury Chair Professor of Secondary Education, State College, PA BA—Earth Science Education, University of Maryland MA—Michigan State University PhD—Science Education, University of Maryland	Duschl

Primary employment	*Educational background*	*Surname*
	Professor, Science Education, East Lansing, MI BA—(not listed) MA—(not listed) PhD—Science Education, University of Iowa	Krajcik
	Associate Research Professor, Portland, OR BA—Astronomy, Harvard College MA—Science Education, UC-Berkeley PhD—Science Education, UC-Berkeley Certification—Secondary Science Teaching, UC-Berkeley	Sneider
Career Scientist and Science Education Researchers (dual activities)	Professor of Geology/Science Education, San Jose, CA BS—Geology, Hunter College MS—Guidance and counseling, Long Island University MPhil—Environmental sciences, City University of New York PhD—Earth and Environmental Sciences, City University of New York	Messina
Career Education Researchers (interdisciplinary)	Professor, Science Education and Diversity and Equity, New York, NY BA—English, Kyungpook National University MA—Educational Psychology, Kyungpook National University PhD—Educational Psychology, Michigan State University Certification—TEFL (teaching English as a foreign language in secondary school), Kyungpook National University	Lee
Business Leaders (includes educational consulting companies and STEME industries)	Director of Field Impact, Student Achievement Partners, New York, NY BA—Biology, Rutgers University MA, PhD/ED—Educational Leadership, Rowan University	Alberti
	Chief Engineer, Boeing Phantom Works, Seal Beach, CA BS-Aerospace Engineering, Northrop University	Friend
	Senior Research Associate, DuPont, Greenville, DE BS/MS—Electrical Engineering, University of Missouri-Columbia PhD—Electrical and Computer Engineering, Georgia Institute of Technology	McQuade
	Westbrook Consulting Services, Austin, TX BA—Education, Texas Women's University MET—Science, Math, Technology Education MA—Interdisciplinary Studies Certification—ESL, Business Education	Westbrook

APPENDIX F



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APPENDIX G

Media Analysis Guide—How a source represents scientific problems

Topic:
Title:
Author:
Publisher:
Publication Date:

1. How is _________ defined?

2. What tools for thinking about ________ are presented?

3. What historical or contemporary scientists are featured, if any?
   a. How many were men?
   b. How many were women?

4. How are children represented (e.g., boys vs. girls, conducting investigations vs. narrating facts)?

5. How were men and boys depicted in images or photos in the book, and what were they doing?

6. How were women and girls depicted in images or photos in the book, and what were they doing?

7. What connections are made between:
   a. Past theories and contemporary theories?
   b. Explanations and everyday phenomena?

c. Phenomena and models?
d. Contemporary problem posing?

8. Are models misrepresented as discoveries or are they, more appropriately, represented as syntheses created by people?

9. What tools for thinking about science are promoted (e.g., anyone can contribute or only experts can contribute, it's anonymous or it's the work of real people)?

10. Is a single story presented, or multiple stories?

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ABOUT THE AUTHORS

Susan A. Kirch is an Associate Professor of Science and Childhood Education at New York University in the Department of Teaching and Learning. In 2012 Kirch was recognized by the Steinhardt School for a *Teaching Excellence Award* for her work preparing elementary science teachers for teaching science as well as doctoral candidates who are interested in science education systems more broadly. Prior to becoming a science teacher educator Kirch began her career at Mount Holyoke College, then Harvard and UCSF as a molecular biologist working with mentors and colleagues in evolutionary molecular biology, immunology, and developmental neuro-genetics to publish articles in *Science, Development*, and *Proceedings of the National Academy of Sciences,* among others. After participating in a variety of initiatives designed to bring teachers, K-12 students, educational researchers, and scientists together to study access to science, Kirch was inspired to switch her research focus from the biological sciences to science education. Since then the partnership with Amoroso has become an unparalleled space for idea generation, critical science curriculum production, and collaborative exploration with children, which have fueled her interests in how learner-scientists contribute to scientific knowledge creation as well as understanding the reconstruction of process-tools such as evidence, causality and relevance in school classrooms. Kirch is particularly curious about the nature of scientific inquiry that all students experience in and out of formal school contexts. In 2008 (with Anna Stetsenko and Catherine Milne), she received a National Science Foundation award to study how children experience the concept of evidence. She has published chapters and articles with colleagues in education on school funding, inclusion, feminist pedagogy, curriculum, evidence and knowledge production, and the production and resolution of uncertainty in science and science classrooms. This book with Michele Amoroso is her first.

Michele Amoroso is a native of Queens, New York. She has been a New York City public school teacher in her community for twenty years. Amoroso worked days as a hairdresser while she attended night school to eventually obtain certificates in early childhood and childhood education, administration and supervision, and a master's of science in elementary education. Since then Amoroso has taught early literacy, math, social studies and science and always strives to create rich contexts for learning through taking socio-cultural approaches to curriculum development and instruction. She continues that approach in her current position as a prekindergarten through third grade science teacher for approximately 300 young learner-scientists who rely on her for learning in all fields of science. Amoroso's desire to be a teacher-researcher was realized when she met Kirch at a routine professional development workshop. Everything but routine, their decade-long research collaborative is detailed in this book and continues to powerfully transform her current practice as an elementary school science teacher. This research collaboration also informs her work in teacher education as an adjunct lecturer in the areas of science, mathematics, and literacy education at her *alma mater* Queens College, CUNY. Amoroso has presented her research at several education conferences including those sponsored by the National Association of Research in Science Teaching and the Association of Science Teacher Educators organizations. She is also the author of a handbook chapter demonstrating the development of an Earth and space science lesson for an early childhood audience. Her future work with Kirch will likely expand on the work reported here. This book with Susan Kirch is her first.

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