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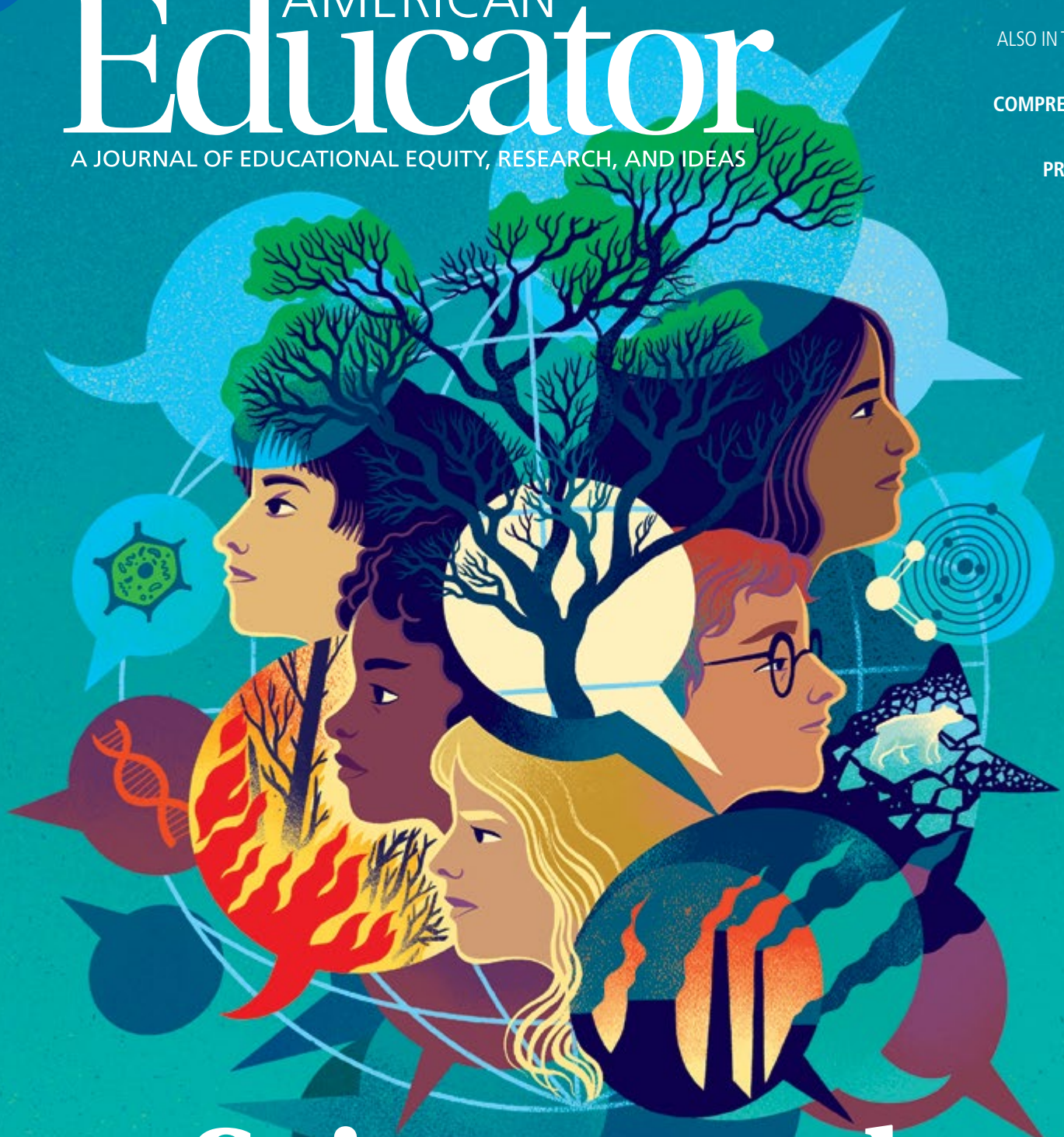
AMERICAN Educator

A JOURNAL OF EDUCATIONAL EQUITY, RESEARCH, AND IDEAS

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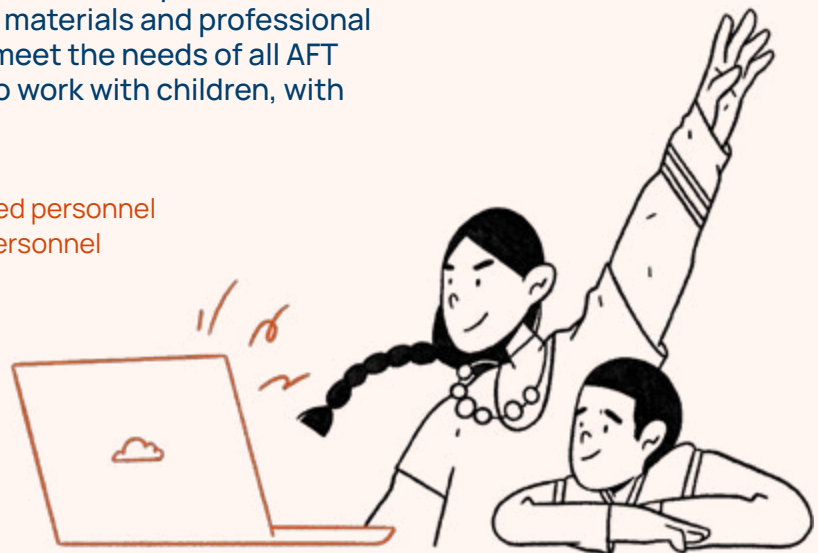
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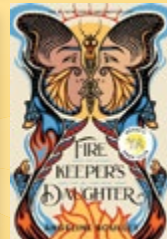
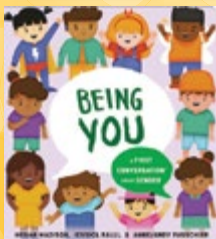
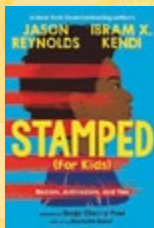


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Empathy for All

Together, Parents and Teachers Help Students Thrive

RANDI WEINGARTEN, AFT President

THIS IS A fraught time. COVID-19 has been deeply disruptive to families. Even though kids are back in their classrooms, it has been a very tough school year. I've seen students' joy as they learn alongside their friends and teachers, and I've seen their social and emotional struggles as we all endure the uncertainty and anxiety of the ongoing pandemic.

Just as we all need to be pulling together, there are divisive forces pouncing on families' fears to stoke division—fears many people have about the effects of the pandemic and school closures and fears some people have over a growing racial reckoning. Culture warriors, who have turned basic COVID-19 safety precautions into ideological battles, are now trying to make any discussion of race, racism, or discrimination toxic. They are bullying teachers and trying to stop us from teaching accurate history. They are also touting “parents' rights” as a way to force extreme views into public schools' curricula.

Public schools need to be safe and welcoming, particularly now. Our students need to be prepared for life and culture, for career and—yes—civic engagement. These culture wars are the opposite of what we need. They divide, when parents and teachers have to be each other's partners. We have to work together—it's how we help kids thrive.

We need to have *real conversations* about the importance of learning from a common curriculum, teaching accurate history, and having empathy for everyone, especially during these uneasy times. And while every child should know our country's history—the good and the bad, in an age-appropriate way of course—no child should be made to feel bad about who he, she, or they are. That goes for gender, religion, skin color, sexuality, or any aspect of identity. Learning to treat each other as we would want to be treated, to discern fact from fiction, and to engage with others on

uncomfortable issues will help our students be prepared for their lives.

I was a high school social studies teacher. I taught difficult but important topics, including the effects of slavery, and I know how important it is to create empathy for everyone—students and families—so that the classroom is a safe and welcoming environment. Since George Floyd's murder, many Republicans have claimed that making students feel bad is part and parcel of learning about racism in America. That's not true. Our kids are not responsible for the past. But learning about the past helps prepare them, in the words of the Constitution, for “a more perfect Union.”

Parents, teachers, administrators, and community members have to work through these issues together. We have to listen to each other. I talk to parents frequently—including parents who disagree with me. When we talk, we find ways to trust, and we find common ground. Despite what the culture warriors claim, there's a lot of common ground on teaching honest history. A *USA Today*/Ipsos poll conducted this fall found that about three-quarters of parents want their children to learn about slavery and racism in school. Teaching history is a crucial part of teaching students how to think critically. When we do that, we move this country to a fairer, more just place.

Learning to think critically is all the more important now that misinformation and disinformation are everywhere. In this issue of *American Educator*, high school science teacher Alyson Miller explains how she approaches controversial topics like evolution, climate change, and race. She establishes trust with and among her students. Then, she gets to know her students and their beliefs so she can meet them where they are.

We should apply these lessons to all the issues around schooling this year. Take vaccines. We know they are safe and effective. While we believe they are

our best chance to beat the pandemic, we need to meet families where they are and empathize with them as we share the facts. This is what educators are doing, and it's working: according to an Axios/Ipsos poll in early November, 75 percent of parents think their local schools are doing a good job balancing health and safety with other priorities.

When we talk, we find ways to trust, and we find common ground.



We all want to get our lives back—without masks, social distancing, or quarantines—and we all want our kids to get their mojo back. The bottom line is that parents and educators are partners in children's education and well-being. We've got to work together to ensure every public school is a place where parents are happy to send their children, educators want to work, and children thrive. □



Science and Citizenship: Fighting Misinformation with Education

Misinformation weakens our democracy by stoking distrust and incivility and deepening inequities. Teaching students to recognize misinformation and counter it with evidence-based reasoning empowers them to engage responsibly in civic life and help build communities where everyone can thrive.

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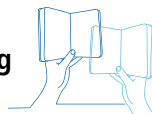


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OUR MISSION

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KASIA BOGDANSKA

Supporting Refugees and Immigrants Who Have Experienced Trauma

The United States has a long history of exclusionary immigration and refugee policies. Biases casting certain immigrant and refugee groups as threats to Americans' health, safety, and economic well-being underlay our unwillingness to aid Jewish refugees in the 1930s, resentment of Vietnamese refugees in the 1970s, and searing images this fall of federal agents on horseback chasing Haitian migrants from the US-Mexico border.

2021 has been brutal for the people of Haiti and Afghanistan, as political upheaval in both countries—and a magnitude 7.2 earthquake in Haiti—has resulted in many thousands seeking a new start in the United States. This school year, classrooms across the country are welcoming new Haitian and Afghan students. Many are still reeling from the trauma of their experiences, and their academic, social, and emotional needs are immense.

Here, we highlight resources to help educators support these students in their transition, create awareness about immigrant and refugee experiences, and build welcoming, inclusive classrooms.

Creating Awareness Through Storytelling

Storytelling can create empathy for and understanding of human experiences. In "Telling the Family Story," students in grades K–5 narrate and illustrate their immigration experiences and receive printed copies to share. Created by a teacher of English language learners who won a grant from Share My Lesson partner Teach Immigration, a key goal is for children to share their stories in public readings to acknowledge immigrants' struggles and celebrate their triumphs.

Older students can combine storytelling with technology in "Podcasting the Immigrant Experience," a three-week teacher-designed unit (also from Teach Immigration) intended for eighth grade. Students record and edit interviews of family or community members to create stories of immigrant experiences that enrich their understanding of the triumphs and struggles of building a new life in the United States.

For grades 9–12 is *Brave Girl Rising*, a 20-minute film about 17-year-old Nasro, a



FG TRADE/E+/GETTY IMAGES

refugee from Somalia. The story is told through five poems that highlight Nasro's experience of leaving home to exist in "the in-between" and celebrate the resilience of refugees. The accompanying resources by Share My Lesson partner Girl Rising include a character map, discussion and reflection questions, and a fact sheet detailing the impacts of the refugee experience on children and families.

Building an Inclusive Community

Acclimating to a new culture is stressful—and this stress is compounded when newcomers encounter racism, xenophobia, or anti-immigrant sentiment in their schools and communities. Educators can help by better understanding the factors that make moving to a new place with a new culture so stressful and ensuring new students feel welcome, represented, and supported in their classrooms.

"Understanding Immigrant Trauma," a resource guide created by Share My Lesson partner the Immigrant Learning Center, includes practical tips for teaching and advocating for new students. The Share My Lesson webinar "You Are Welcome Here" and Colorín Colorado's "Welcoming Afghan Families" provide lessons learned from Dearborn Public Schools in Michigan and the Austin Independent School District on preparing for and supporting immigrant students who have experienced trauma. (Bonus: the SML webinar offers one hour of professional development credit.)

Finally, students can learn from the example of a Vietnamese community in Seattle that is reaching out to Afghan refugees. This resource for grades 6–12 is based on an episode of the PBS NewsHour

Extra series "Chasing the Dream" that highlights Viets 4 Afghans, a group created to support the resettlement of recent evacuees from Afghanistan. Following the video, students reflect on similarities in refugee experiences, the challenges of resettlement, and ways that they can help.

These are just some of the resources available to help support students with traumatic immigration experiences and help reframe the immigration narrative with empathy and understanding. Please share your expertise by uploading your lesson plans at sharemylesson.com and reach out to us with any additional ideas or requests at content@sharemylesson.com.

—THE SHARE MY LESSON TEAM

Recommended Resources

To access these free resources, visit aft.org/ae/winter2021-2022.

Telling the Family Story

Podcasting the Immigrant Experience

Brave Girl Rising: The Refugee Crisis and Human Responsibility

Understanding Immigrant Trauma

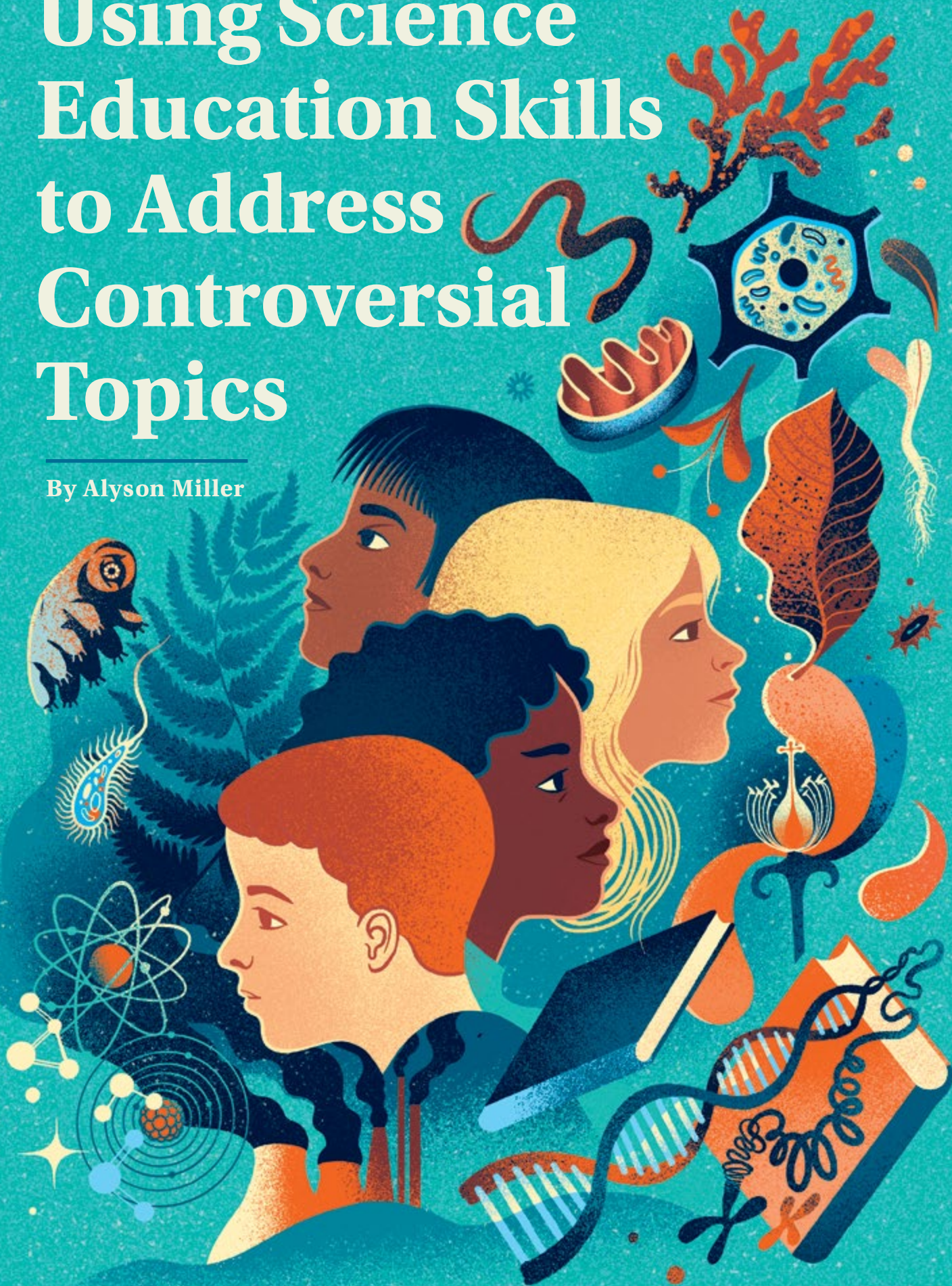
You Are Welcome Here: Supporting the Social and Emotional Needs of Newcomer Immigrant Students

Welcoming Afghan Families: Lessons Learned from Austin ISD

How Seattle's Vietnamese Community Is Helping Afghan Refugees

Using Science Education Skills to Address Controversial Topics

By Alyson Miller



“Do they not want us?” I overheard a high school student ask a small group of peers, all recent immigrants to the United States, on the morning after the 2016 presidential election. I rushed to get to the faculty bathroom and back to my classroom in the five-minute break between classes and pretended that I had not heard him, a former student of mine. Normally, he was confident and funny, secure in his popularity among other students, but the catch in his throat bothered me. I should have stopped. I should have said something, anything, to comfort him—but I didn’t. I rushed to class.

As soon as I walked into the room, my students pummeled me with questions.

“Who’d you vote for, Miss?”

I’m a white, middle-aged science teacher who wears pearl earrings, Top-Siders, and oversized tortoise-shell glasses. My students—42 percent of whom were enrolled in the free or reduced-price lunch program, 60 percent of them white, 27 percent of them Hispanic or Latinx (and the rest Black, Asian, Pacific Islander, or multiracial), 7 percent with limited English proficiency—couldn’t tell from the way I dressed if I had voted for the winner or the loser in that election, and they demanded to know. It was still early in the school year, and they hadn’t made up their minds about me. Was I with them or against them?

“I’m not telling you,” I said.

“The other teachers told us,” one said. “It doesn’t matter now if you tell us or not.” A wall of male students sat on top of their desks, arms crossed defensively, eyes squinting, practically daring me to give them an answer that they didn’t want to hear.

I paused, weighing their argument. Technically, it didn’t matter since the election was over and my choice of candidate would not affect their voting behavior or that of their family members. Yet announcing my political views could alienate some students, and that was unacceptable.

“First,” I said, “my vote is private. It’s personal, and I don’t have to tell anyone how I voted.”

They didn’t move. Maybe a few lips thinned in disapproval.

“Second,” I said, “what I believe in more than anything else is equality.” I looked down at my desk, away from their eyes. “It’s in our Constitution that all men are created equal, and I believe in that more than I believe in anything else.” I looked back at them. “That means that if I voted for the winner, and you or your family didn’t, then you might perceive me as being a little superior to you. Or if I voted for the loser, and you voted for the winner, then you might think that I’m inferior to you. I’m not telling you who I voted for because you and I are equal, and I’m not going to say anything that would jeopardize that. Period.”

It was the only time in my nearly 20 years of teaching that I received a standing ovation, and I instantly had the ear of those students. Later, if I said something that they disagreed with or did

Alyson Miller teaches science at Nashua High School North in Nashua, New Hampshire. Since beginning her teaching career in 2003, she has taught zoology, biology, physical science, plant science, and physics classes. She was a charter member of the AFT Teacher Leaders Program, and her project led to her winning a scholarship from the National Center for Science Education to learn about “Deep Time” by rafting and studying the Grand Canyon. Prior to becoming a teacher, she was a research supervisor with Yerkes National Primate Research Center at Emory University.

not want to believe, they respected me enough to listen. That’s a really big thing when it comes to teaching science because we educators are tiptoeing through political and religious minefields as we teach climate change, evolution, and genetic engineering. Some of our students shield themselves against us before they ever hear a word we say. How can we—aside from building on questions that students bring to the classroom during political elections and other major events—use techniques that we’ve honed as science educators to prevent students from being susceptible to propaganda, pseudoscience, and misinformation? Just as importantly, how can we feel confident enough in our content knowledge to stride boldly into those minefields?

Our common ground is the earth beneath our feet. Every human on the planet has survived an obstacle-filled marathon of epic proportions.

How Science Informs Politics: Diversity Is Necessary for Survival

How many times do we educators hear the mantras “develop relationships with students” or “add a personal touch”? We know we will be better teachers if we connect with our students, but how can we if they come from very different backgrounds than we do? How do we find common ground?

Our common ground is the earth beneath our feet.

Confession time: My passion for equality transcends the US Constitution. In fact, it’s more of a mass celebration of survival than a political construct, and it informs the way I interact with everyone—whether or not I agree with their political views. Sharing my mindset has helped students who were dealing with depression, grabbed the attention of reluctant learners, and provided a starting point for political discussions with adult friends outside of the classroom.

So what is it?

It’s that every human on the planet today has survived an obstacle-filled marathon of epic proportions. We should be patting each other on the back for making it through the race instead of trying to knock down our fellow competitors—whose help we might need to get us over unknown hurdles in the future.

Early in the school year, I ask my students to think about their parents and grandparents and the wars, poverty, or hardships in faraway lands that they may have experienced. Then I have them think farther back to the last 200 years and of world wars, genocides, pandemics, famines, and droughts. Their families suffered,

yet in every generation someone had a child who survived long enough to have a child of their own and pass bits of the family DNA into the future.

Again, no matter how bad things got, someone had a child and that child lived and had a child until the child of that child ended up in my classroom. Wow.

But don't stop there. That unbroken chain of children keeps going back through time and then dives into Deep Time.* For millions and maybe even billions of years, a little baton of DNA was passed from one generation to the next. Yes, it changed and mutated as the environment changed, but it kept going through ice ages, tectonic shifts, floods, and *five* mass extinction events. When a meteor wiped out almost all of the dinosaurs,¹ when a mountain range of volcanoes spewed toxic gases into the air and killed nearly everything on the planet, and when oxygen levels spiked or plummeted, someone (or something) had a baby (or the equivalent) that lived, passing on tiny bits of DNA to another generation like little candles of life, until they plopped into the too-small desk chairs in front of me.



As educators, we gain patience, compassion, and respect when we cherish our students as fellow survivors in the struggle for existence.

Students, no matter how easy or how difficult their lives are now, must understand on a deep, visceral level that they have what it takes to overcome adversity. The gene that told their developing bodies to make a right side and a left side goes back 500 million years.² Inside their bodies are bits and pieces that survived *T. rexes* and megalodons. DNA is the most amazing molecule in the universe, and it's in every cell in their bodies as a tiny reminder

*Deep Time refers to the multibillion-year history of Earth as represented in the geologic time scale and supported by geological and chemical evidence. For more information, see go.aft.org/emc.

of the thousands of generations that kept going long enough to pass the torch to them.

As educators, we gain patience, compassion, and respect when we cherish our students as fellow survivors in the struggle for existence. Some of them experienced traumas that no one—ever—should endure. Others suffer from mental health issues that jeopardize their chances to lead satisfying lives. Teaching them the history of their body's journey through time can bolster their ability to cope—and ours.

How can we teach this? During my first year of teaching, an administrator wisely advised me to find my voice. Every teacher is different, and no single method works for everyone. I happen to be passionate about Deep Time, so I listen to podcasts such as *The Common Descent Podcast* and *Paleo Nerds* for fun. After giving students time to reflect on the obstacles faced by their immediate ancestors, I assign students to create comic books, to write short stories, or to add panels to a hallway-long geologic timescale that tells fictionalized autobiographies of their DNA. My goal is not to be persnickety about different genes mutating at different frequencies and coming and going from the human genome; instead, my point is to hammer home that life on Earth is very, very old, and that their roots run deep.

Students must also understand the importance of valuing the traits that make us different from each other. When we study ecology, we discuss affiliative behavior and how cooperation helps species survive. We also discuss the importance of genetic diversity and of having the largest possible gene pool in case environmental changes demand a new toolkit. Like deforestation that may wipe out a hidden cure for cancer, “wiping out” people who are different from us could cost us the ability to adapt to a changing environment. Embracing our differences and recognizing each other as fellow shipmates on the journey into the future is not a tree-hugging political statement; it is a mandate for survival.

How Science Leaves Room for Religion: A Search for Natural Causes

Science is the study of the *natural* world.

For years, I thought that was an awkward definition of science left over from the days before Thomas Beddoes invented the term “biology” in 1799, back when many scientists were called “naturalists.” Then I finally got the punchline: science is the study of things that can be measured, *natural* things, as opposed to the study of the *supernatural* world.

Because one of the goals of science is to figure out causes (independent variables) and their effects (dependent variables), there is no place for supernatural causation in a science classroom. I make it very clear that supernatural beings may be “out there,” but science—by definition—limits itself to the natural world.

To my utter shock and delight, I discovered that students quickly grasped the concept of the natural versus the supernatural worlds. Before having this thump-on-the-head insight of natural versus supernatural causation, I didn't know how to respond to students who claimed that something was “God's will.” Now, without offending their religious beliefs, engaging in debates about creationism/intelligent design, or trying to explain the First Amendment's Establishment Clause (on the separation of church and state), I simply say, “that may be true, but it assumes

supernatural causation, and we can't test that. Alas, in science we are limited to studying the natural world."

Studying the natural world requires collecting measurable data. Those data are plugged into statistical formulas that determine the likelihood of x causing y . Measuring the natural world often starts with our sense organs, but we've discovered that our senses are limited. For example, we cannot hear the low-frequency calls that elephants use to communicate over long distances. We cannot see the patterns on butterfly wings and flower petals that are only visible under ultraviolet light. We cannot smell the aphrodisiac pheromone (called seducin) released by some male cockroaches. Unlike the duckbill platypus or the great white shark, we cannot feel the electricity given off by distant underwater animals—and unlike some birds, we cannot sense the Earth's magnetic field. Because we cannot sense these events ourselves, can we classify them as part of the natural world?

Yes, because we have developed tools to expand the deficiencies of our sense organs and can reliably measure these events. That is how we are able to tell the story of Earth's history, too—by analyzing chemicals in sediment samples and ice cores, recording types and numbers of fossils, and even breaking open microscopic crystals to measure the components of the atmosphere that were trapped inside them billions of years ago. If the data provided by these tools are reliable—giving similar results under consistent conditions—then we can accept the results as scientific.

What if something is so small or so far away that we can't measure it? Physicists have argued over whether string theory, for example, is a scientific theory or speculative philosophy because there are no tools that can measure anything as small as a subatomic "string."³ Without measurements, data cannot be collected to support or falsify a theory. In other words, if there is no way to prove it wrong, then it cannot be a scientific theory. But string theory could be proved wrong—or right—if *tools were available* to detect the tiny strings. Today, most scientists agree that because the theory could be tested with as yet unavailable tools, it should be accepted as a scientific theory offering a viable option for reconciling discrepancies between quantum and gravitational physics.

String theory shows us the boundary of science. If we cannot or could not measure or "quantify" something, then it should be discussed in philosophy or religion classes. No hard feelings, no judgments, but science is limited to the natural—not the supernatural—world.

How Science Clarifies Controversies: My Approaches to Three Perennial Challenges Human-Induced Climate Change

I don't think there's a single topic in science education that makes me fling my head onto my desk and pound my eyeballs the way that climate change does. The graphs and charts and photographs of starving polar bears and numbers and projections overwhelm me. I actually care about it, but ... enough already!

That adage "you can't see the forest for the trees" seems to be at work here, so step back and look at the forest, at the big picture. Teaching climate change requires understanding two things: the carbon cycle and the Carboniferous Period of the Paleozoic Era.

Students enjoy learning about the carbon cycle outside on the school grounds, where they can search for specific examples of plants for photosynthesis; insects, birds, or other animals for respiration; and some sort of human activity for the use of fossil fuels, such as cars, weed whackers or leaf blowers in neighboring yards, HVAC equipment, etc. Having them fill out a blank carbon cycle worksheet with examples or create their own from scratch is a fun way to introduce them both to the carbon cycle and to common organisms living near their school.

Back in the classroom, I review or teach the combustion reaction: hydrocarbon + oxygen \rightarrow heat energy + carbon dioxide + water. Then I ask, "Where did we get those hydrocarbons, also known as fossil fuels?"

Science is the study of things that can be measured, *natural* things, as opposed to the study of the *supernatural* world. Students quickly grasp this concept.

Students tend to have the misconception that they are from squished dinosaurs, but at least they know that the hydrocarbons are ancient and nonrenewable. Spiraling back to Deep Time, we journey 300 million years to the Carboniferous (carbon "bearing") Period when most of the coal-based fossil fuels (including some hydrocarbons, such as oils and natural gas) were formed.⁴ It was the Age of Amphibians, and enormous salamander-like creatures lived in hot, humid swamps. Conditions for plant life were ideal, but eventually plants die. When dead plants fell into swamps, a lack of oxygen in the mud prevented decomposers from picking apart their atoms and returning the carbon to the air.[†] The carbon that made their bodies was trapped underground. Over millions of years, carbon was removed from the atmosphere much like socks are lost in a dryer and "removed" from the laundry basket. With less carbon in the air to form greenhouse gases (such as carbon dioxide), temperatures cooled, the air became less humid, and swamps dried up. The new conditions marked the end of amphibian dominance and ushered in the Age of Reptiles. (Dinosaurs came later in the Age of Reptiles.)

Hundreds of millions of years passed, and reptiles gave way to birds and mammals—all of us evolving to live in the cool, dry conditions caused from having fewer carbon-based greenhouse gases to act as an atmospheric blanket to keep us warm.

Then humans invented the combustion engine, drilled into the deeply buried old swamps to suck up the trapped carbon, and in less than 300 years pumped tons of it back into the carbon

[†]For more details, see the Smithsonian's "The Age of Oxygen," available at go.aft.org/cgk.

cycle—like suddenly finding all of the lost socks and putting them back into the laundry basket all at once.

Data from the National Oceanic and Atmospheric Administration show that since 1750, the onset of the industrial revolution, levels of carbon dioxide in the air have risen 46 percent.⁵ Greenhouse gases trap heat, and carbon dioxide accounts for 80 percent of the heat that is trapped. Earth got very warm very fast. Too much, too soon?

Did the sudden use of fossil hydrocarbons by humans cause the climate to change? Is my laundry basket suddenly too heavy to carry?

Students, like the rest of us, are inundated with information about the effects of climate change on our environments. Scary pictures and talk of the horrors of climate change can be so overwhelming that students—and adults—often either shut down and ignore it or deny that it's true. By offering a simple story that is logical and testable, we educators can provide a starting point for discussions and for research projects on what we can do to help.



By offering a simple, testable story of climate change, we provide a starting point for research on what we can do to help.

Evolutionary Theories

My father was a fundamentalist preacher. My 97-year-old mother still takes offense that anyone would suggest that humans “descended from monkeys.” Growing up in a family that found the “E” word more offensive than the “F” word and that rewarded my sister for refusing to listen to the “sacrilegious” ideas espoused by her high school biology teacher, I get it. I know exactly how difficult it is to teach students who actively refuse to participate in lessons in which the “E” word is used.

Being matter-of-fact about *human* evolution through natural selection as a noncontroversial, well-documented theory that has withstood over 150 years of constant challenges should not be

difficult. Yet it often is. I use several strategies to avoid threatening the core belief systems of my students and therefore shutting down their learning process.

“Nothing in Biology Makes Sense Except in the Light of Evolution” is the title of a widely read essay by evolutionary biologist Theodosius Dobzhansky.⁶ I take this very seriously, using the term “evolution” often. In my classroom, *evolution* is infused in every unit or science standard. There’s a lot to say about the evolution of cells, genes, and how organisms interact with each other and their environments, and using the term frequently helps students habituate to it. I’ve had no pushback, for example, about teaching the endosymbiotic theory that explains how mitochondria became a part of eukaryotic cells.

Knowing that anti-evolutionists come up with new challenges every year, and that teachers are often uncomfortable or lack the content knowledge necessary to respond effectively, I recommend privately watching the Nova documentary *Judgment Day: Intelligent Design on Trial*. Although it is over 10 years old, the documentary is still my go-to resource as a two-hour master class on understanding the nature of science and the legal ramifications of allowing supernatural causation into science classes, and for rebutting false claims of “irreducible complexity” or “it’s just a theory.” I’ve rewatched that documentary dozens of times.

At the beginning of the school year, I anonymously survey the students about various topics, including evolution. Some students mention that it goes against their religious beliefs, so later in the year I’ll make two offhand comments. The first is that many religions recognize that the human body evolved through natural processes. For example, 25 years ago Pope John Paul II recognized that “the theory of evolution is more than just a hypothesis.”⁷ These religions claim that the “soul” of man (a supernatural construct, so it’s beyond us science people) did not evolve. My second comment is that evolution does not explain how life began. Instead, it explains how organisms changed and diversified into millions of species over time. So far, scientists have been unable to create life from nonlife.

I vividly recall my own days as someone who did not “believe” in evolution and how difficult it was for teachers and friends to chip away at the defensive wall I had built against it. By conceding that we don’t know how life began, educators give resistant students the chance to step back, take a breath, and feel as if they have permission to learn about common ancestry because their religious beliefs are not threatened.

While some nonscientists are still arguing whether evolution is real, scientists are not. Scientists are now moving into the third phase of evolutionary thought, while many nonscientists have yet to accept the first one.

Phase I. Darwinian Evolution: The Theory of Evolution Through Natural Selection (Late 1800s)

In *On the Origin of Species*, Charles Darwin claimed that organisms evolve, or change over time, mainly through natural selection (i.e., the struggle to survive).⁸ Prior to his work, it was commonly believed that species did not change. He showed that they did change, that modern species descended from common ancestors, and that they were still changing. Gregor Mendel lived at the same time as Darwin and was very familiar with Darwin’s work, but Darwin was not aware of Mendel’s classic experiments showing how traits were passed on to different generations in plants.⁹

When introducing the evolution unit or standard, I use this simple explanation of evolution as the unintended consequence of three facts:

1. Organisms reproduce (replication).
2. The offspring are not identical (variation).
3. Some offspring pass more of their genes to the next generation than others (selection).¹⁰

I keep the topic as simple as possible by sticking to Darwin's examples of artificial, natural, and sexual selection.

There are standard examples of evidence for evolution, and I tend to cover them quickly because I prefer devoting more time to recent discoveries. Although I switch up the examples as I find new ones, I generally teach fossil evidence (*Tiktaalik*, *Archaeopteryx*, flatfish), homologous and vestigial structures, and direct evidence of evolution (bacteria, London Tube mosquito, Tennessee cave salamanders).

Phase II. Modern Synthesis: Merger of the Theory of Evolution with Mendelian Genetics (Mid-1900s)

In this phase, the definition of evolution was changed to reflect the role of newly discovered genes in the process of evolution: evolution is the change in the frequency of alleles within a population (i.e., a gene pool). Much of this phase is covered under the topic of genetics or heredity, and it includes how traits are passed to offspring through the process of meiosis. Some variation in traits is due to mutations during DNA replication and to recombination, or crossing over, in homologous chromosomes. For a long time, scientists thought that this was the main source of variation.

Phase III. Evo-Devo: Evolutionary Developmental Biology (Current)

About 15 years ago, the scientist and science educator Sean B. Carroll proposed that evolution of form should be defined as a change in development.¹¹ Carroll, a leader in the new science of evolutionary developmental (evo-devo) biology, studies how animal bodies form before they are born.

During the 1970s, scientists discounted a lot of DNA as wasteful “junk” because it did not code for proteins. We now know that some of that “junk DNA” is the software for creating our bodies from a single fertilized cell. In terms of biology, this is where the action is. This is where the “variation” part of evolution takes center stage because the genes on this DNA *regulate* other genes, switching them on and off to guide where cells go in an embryo. “Accidentally” leaving them on or off too long creates different body plans, sometimes leading to biodiversity.

Such genetic “toolkits” date back millions of years and are shared by all bilaterally symmetrical animals. For example, they signal cells to form arms and legs at certain places on the embryo. They also direct the building of backbones, chunk by chunk. As Carroll notes, each chunk of backbone takes 20 minutes in zebra fish and two hours in mice. If the “backbone” gene turns on or off at the wrong time, then animals can be born with very long (or very short) backbones. This process can lead to rapid changes in the phenotype and may account for sudden changes in the fossil record, described as “punctuated equilibrium” by paleontologists Niles Eldredge and Stephen Jay Gould.¹² Imagine the diversity of animals that results from different modules of the body being made at different rates!

Or don't merely imagine it. Scientists proved that ancient genes can be turned back on when they grew chicken embryos with teeth and a crocodile-like snout. When human regulatory genes were used in fruit flies, they worked—they turned on the genes that directed the fly to make its body. This indicated a shared ancestry dating back millions of years.

Evo-devo is making rapid advances in understanding both our history and how environmental toxins can cause regulatory gene malfunctions. Discoveries are being made so often that it's difficult to keep up with them. I encourage my students to keep up for me by assigning them research projects to present to the class. They choose their topic, and I help them craft a measurable question to focus their research. Because each student chooses a topic that interests them, it is easy to modify the project for students needing individualized educational plans, English or dual language supports, or other accommodations. For the past few years, questions in evo-devo have topped the list of chosen topics. I'm convinced that the topic is so popular because it ignites their imaginations. As Einstein said, “the most beautiful thing we can experience is the mysterious. It is the source of all true art and science.”¹³

By conceding that we don't know how life began, educators help resistant students learn about common ancestry.

Regardless of their academic level, my students work with school librarians for one week to learn how to use scholarly databases and to research a single biology topic in depth. They present the project to the class when we are studying the science standard related to their topics. Other than topics in evo-devo, many students choose topics on bioethics, curing genetic diseases, and how tools like CRISPR work. (Before they present their projects, I review each with the individual students for clarity and accuracy—and so the students are confident about their topic while presenting.) Year after year, I'm impressed with both the students' choices of research questions and the latest information they've discovered. This is where we baby boomers and Generation X'ers step back and applaud what's coming.

Race

Humans have been called “the naked ape.”¹⁴ Of the hundreds of primate species alive today, we are the only ones that are not covered in fur. For most of our history, we did not have access to clothes, so our skin was constantly exposed to sunlight—and

the amount of sunlight often meant life or death for our children.

If a pregnant woman is exposed to so much ultraviolet light that folic acid molecules break down, then her child may be born with spinal deformities such as spina bifida.

If a child doesn't get enough ultraviolet light to produce vitamin D, then bones cannot absorb calcium and rickets develops; in females, the pelvic bones may become so distorted that childbirth is affected.



Skin color gently changes from dark to light as the intensity of sunlight decreases. Skin color evolved through natural selection. It's that simple.

Reproduction, the number one requirement for evolution to take place, is heavily in play here. Fortunately, our skin can produce a natural sun-blocking pigment—melanin—to block UV rays. So what's the perfect skin color? What is the Goldilocks combination of skin color and sunlight that will provide enough UV rays to prevent rickets while not causing spinal problems?

It depends on where the person lives.

Nina Jablonski, an anthropology professor who studies the evolution of skin pigmentation, revolutionized the way we think about skin color and how it has adapted to different amounts of sunlight.* She calculated the intensity of UV radiation at different latitudes and overlaid those data with measurements of skin color. There was an 86 percent correlation between skin color and UV intensity, which points to a cause-and-effect relationship. Around the equator, where the sunlight is the most intense, skin color is very dark. Moving toward both the north and south poles, where sunlight is least intense, skin color becomes lighter as melanin is lost.¹⁵

*For an overview of Jablonski's findings with links to several resources, including her TED talk, see go.aft.org/i0x.

There is no sudden boundary between dark and light; instead, Jablonski refers to the subtle changes in skin color as a "sepia rainbow," with each shade blending into the next one.

Very few students are unmoved when they see Jablonski's maps showing how skin color gently changes from dark to light as the intensity of sunlight decreases. Skin color evolved through natural selection. It's that simple.

Skin color, in fact, evolved independently of other traits that may have been adaptive to life in particular environments. For example, having a narrow nose with a lot of warm blood circulating in it helps people who live in very cold climates heat the air that they are breathing. This is beneficial because cold air irritates the membranes in the nose (and throat). But for people living in warm areas, a narrow nose would be inefficient, without a countervailing benefit. Wide noses allow for more air to be inhaled with less effort than narrow noses, so they are more adaptive for people living in warm conditions.¹⁶ Physical traits of humans showcase the astonishing fitness of our bodies to specific environments.

But, ahem, humans are global movers. What happens when a body that is perfectly adapted to one environment moves to a different latitude?

The good news is that we now know that light-skinned people who live close to the equator require extra folic acid during pregnancy (and sun-blocking agents to prevent skin cancer), and folic acid is added to commercial bread products. Dark-skinned people who live closer to the poles must be monitored for vitamin D deficiencies and affiliated disorders that arise from them. Vitamin D is added to milk products to offset some deficiencies. Living in a northern climate, I encourage all of my students—regardless of where they fit on the sepia rainbow—to monitor their vitamin D levels during their yearly physical exams because even the lightest-skinned people may not be spending enough time outdoors to reap the benefits of sunlight. Being aware of potential health issues from living in areas with different intensities of sunlight is vital for maintaining a high quality of life.

Much like our class discussions of climate change and evolution, our scientific explorations of race are far less charged than such discussions tend to be when they focus on perceptions, cultures, or values. In the few years that I've taught skin color as a trait shaped by the environment, I've yet to have a student who already knew this information. When the conversation is focused on skin color as an adaptive trait, students learn something about themselves, their health risks, and their backgrounds that they didn't already know. Like understanding that their DNA has survived millions of years of catastrophes, learning why their bodies look the way they do makes science education deeply personal.

Open the Door to Wonder

Like being the only naked ape, humans are also the only species that asks "Why?" Many animals have learned *how* to do things—New Caledonian crows figured out how to bend wire to retrieve treats from tubes,¹⁷ many animals know how to use rocks to hammer open hard-shelled food—but we humans are alone on our quest to know *why*.

Young children observe the world around them and ask why the sky is blue, why we can't breathe under water, why we must eat vegetables, and an onslaught of other questions. Some of them are fortunate enough to have extremely patient and knowledge-

able adults in their lives who help answer those questions. Many do not. Children may stop asking questions when their curiosity hasn't been rewarded with time and attention. Eventually, they may become disengaged and stop wondering all together.

As science teachers, it's our mission to reengage the wonder. Look at all the cool stuff we have to help us ignite student interest: Deep Time, DNA, evo-devo, skin color, and 30-foot-long amphibians!

It's easy to cut off a student who asks a question that may distract the class from the day's objective. Change your objective. Consider being open to being sidetracked. It's in those moments when an off-the-wall question is thrown at you that you can truly teach the creative nature of science. When a student asked me what would happen if you put a giant MRI machine into orbit over New York City, I dropped everything to step into his imagination and to bring the rest of the class with us. Picturing paper clips flying into the air like upside-down rain and braces being ripped out of their mouths, the students laughed themselves silly and let their imaginations run wild. That's doing science. That's where scientific breakthroughs start. It is in those moments of out-of-the-box thinking that scientists are made.

Why do we teach science if not to open the door to a world of incredulity, of wonder, of knowledge so awe-inspiring that it makes the knees buckle?

Cherishing students as fellow survivors on our rocky planet, celebrating our physical differences because they make our species stronger, and welcoming even the wackiest of questions ignites their interest and acceptance of science. That bodes well for the future. □

Endnotes

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Quick Resources for Teachers

Educators connect with students in different ways, and we generously share techniques and lesson plans through social media groups. Sometimes, however, we must distill truckloads of data and subject matter into chunks of "food for thought" that can be easily digested by students. Spending time reading and listening about our favorite topics in science helps transfer some of our passion for learning to our students—and really, that's all we want, right? These are some of my favorite resources.

- Help for guiding discussions can be found through Talk Science, a free professional development program for inquiry-based science instruction: go.aft.org/69w. Especially good advice on how to clarify thinking, rephrase/repeat, and ask for evidence/reasoning is in the tables on pages 9–13 of this study of the effectiveness of the Talk Science approach: go.aft.org/uwk. And the "talk moves" that are the core of the approach are summarized in this checklist: go.aft.org/271.
- An easy way to drive evidence-based thinking is to use the claims, evidence, reasoning (CER) technique embedded in the Next Generation Science Standard, "Engaging in Argument from Evidence" (see go.aft.org/kin). CER is similar to the talk moves but in written form; it is popular with many teachers because it's easy to apply to most lessons. For more details, see appendix F of the Next Generation Science Standards on "Science and Engineering Practices" at go.aft.org/fhb.
- My favorite podcasts for learning about paleoclimatology, how we know what we know about Deep Time, and fun facts to sprinkle into discussions are:
 - *The Common Descent Podcast*—Hosted by paleontologists David Moscato and Will Harris, this podcast covers a mass extinction in every fifth episode up to episode 100.
 - *Paleo Nerds*—Paleo-obsessed nonscientists Ray Troll and David Strassman interview paleontologists and scientists; they also provide links to engaging resources on their associated website.
- For in-depth understanding of evo-devo, turn to Sean B. Carroll's *Endless Forms Most Beautiful*. The best introduction to the topic is Tim Blais's five-minute video masterpiece, "Evo-Devo ('Despacito' Biology Parody)," available at go.aft.org/tfs. I created a slide presentation that dissects his lyrics frame by frame and use it to drive energetic discussions in class.
- An entire, free curriculum with activities about skin color can be found at Finding Your Roots: The Seedlings, fyrclassroom.org. Developed by Nina Jablonski and Harvard professor Henry Louis Gates Jr., it builds on Gates's "Finding Your Roots" series on PBS, which explores influential people's ancestry. This "Seedlings" version gets young students excited to learn about history, anthropology, genetics, and more as they study their own ancestry.

—A. M.



Teaching About Our Climate Crisis

Combining Games and Critical Thinking to Fight Misinformation



By John Cook

Misinformation damages society in a multitude of ways, and we ignore its negative impact at our peril—especially regarding climate change. While studying how misinformation does damage, scientists have also researched and developed approaches to help build the public’s resilience against misinformation. Teachers are in a powerful position to implement these evidence-based strategies—not only playing a pivotal role in building students’ resilience but also providing deeper, more engaging science education that equips students with sorely needed critical-thinking skills. Much

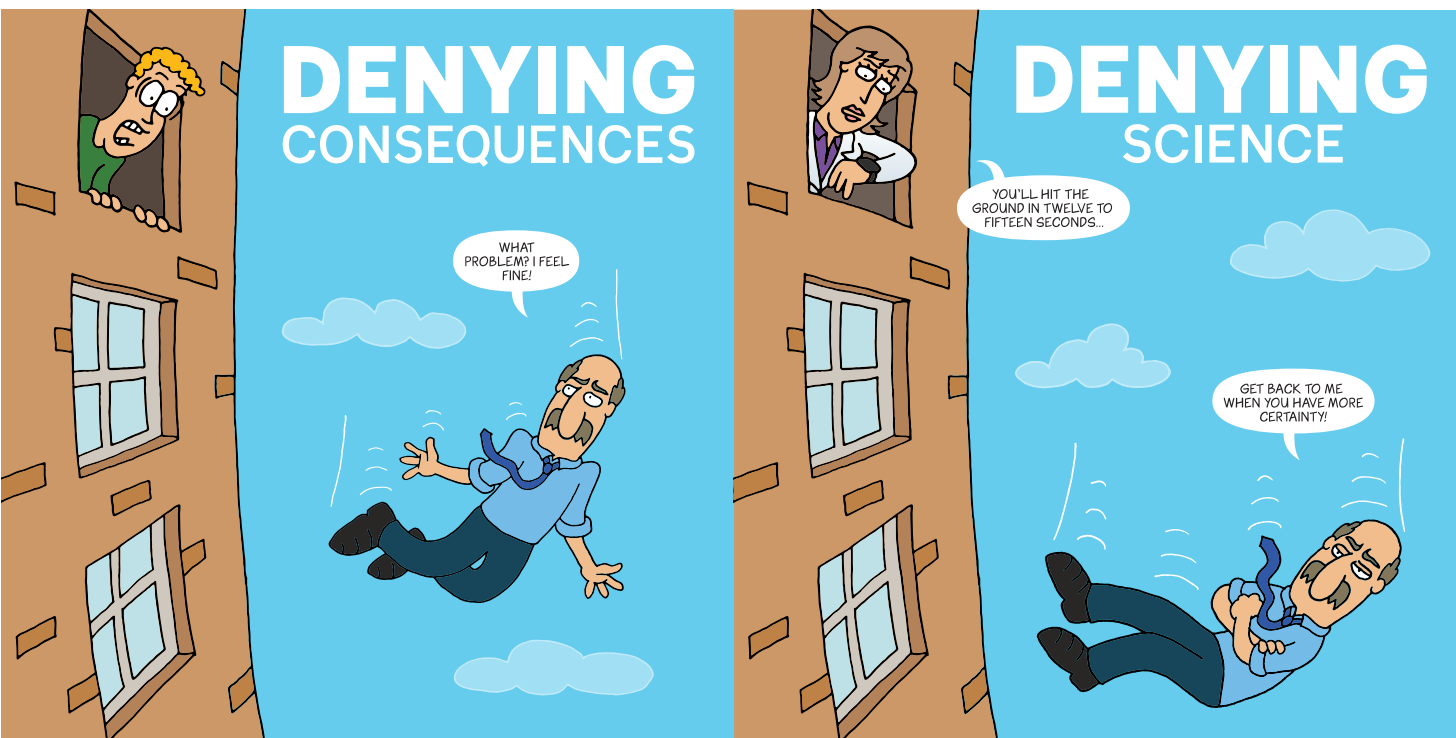
John Cook is a postdoctoral research fellow with the Monash Climate Change Communication Research Hub at Monash University in Australia; he researches how to use critical thinking to build resilience against misinformation. In 2020, he published the book Cranky Uncle vs. Climate Change and the Cranky Uncle game; both combine critical thinking and cartoons to build resilience against misinformation (visit crankyuncle.com). Cook also founded Skeptical Science, an award-winning website that debunks climate myths. Among his many papers and books are two coauthored college textbooks, Climate Change: Examining the Facts and Climate Change Science: A Modern Synthesis, and two books to address climate misinformation, The Debunking Handbook 2020 and The Conspiracy Theory Handbook.

of this article is devoted to sharing those strategies so that teachers and students can effectively counter misinformation, but first, let’s explore how misinformation does damage.

How Misinformation Damages Society

The most obvious way that misinformation does damage is by causing people to believe misconceptions or reducing belief in accurate facts. One experiment found that just a handful of cherry-picked statistics about climate change confused people and reduced their acceptance that climate change was happening.¹ After being shown the misinformation, they also become less supportive of action to reduce climate change. Other, more subtle impacts of misinformation are also dangerous, such as eroding trust in scientific institutions and scientists. As we’ve seen throughout the COVID-19 pandemic, distrust of health experts has led to less adoption of safe behaviors like mask wearing and vaccination, which endangers both individuals and public health.

The effect of misinformation is not identical across different segments of the public. In research my colleagues and I conducted, we found that misinformation about climate change was strongly persuasive with political conservatives but had little impact on political liberals.² This means that as misinformation washes over society, it splits the public further apart, exacerbating an already partisan populace. Misinformation polarizes.



Arguably, one of the most insidious aspects of misinformation is its capacity to cancel out accurate information. In an experiment testing the impact of misinformation that cast doubt on the scientific consensus on climate change, participants were shown conflicting pieces of information.³ One group was shown accurate information about the 97 percent agreement among climate scientists that humans are causing climate change. This consensus message had a strong positive effect, increasing public perceptions of consensus and acceptance of global warming. Another group of participants was shown an excerpt from a prominent example of climate misinformation: the Global Warming Petition Project. This misinformation lists over 31,000 signatories of a petition stating that humans aren't disrupting our climate, arguing that there is no scientific consensus on climate change. As you'd expect, it had a negative impact—reducing people's climate change perceptions. A third group of participants was shown both the consensus and the misinformation. With this group, fact and myth cancelled each other out. This result has significant consequences for scientists, educators, and climate communicators. It means even if we use well-tested, effective science explanations, our efforts can be cancelled out by misinformation.

When people are presented with conflicting pieces of information and don't know how to resolve the conflict, the danger is they disengage and therefore fail to learn from the accurate information. Unfortunately, the information landscape is an uneven playing field. Misinformation doesn't have to be coherent or based on evidence to have an impact. Just by existing, it can cancel out our efforts to communicate accurate facts.

This means that teaching the facts, while necessary, is insufficient. If we fail to equip students with the ability to distinguish between facts and misinformation, we leave them susceptible to being misinformed and our facts vulnerable to being under-

As misinformation washes over society, it splits the public further apart, exacerbating an already partisan populace.

mined. Fortunately, this dynamic also points to a solution to misinformation. If the problem is that people can't resolve the conflict between fact and myth, then the answer is to help them resolve that conflict. We achieve this by explaining the misleading techniques that promoters of misinformation use to distort the facts.

Inoculating the Public Against Misinformation

Inoculation theory is a branch of psychological research that offers a framework to help counter misinformation. It takes the principle of vaccination—building resistance to a disease by being exposed to a weak version of the disease—and applies it to knowledge.⁴ By exposing people to a weakened form of misinformation, they can develop “cognitive antibodies” or “immunity” against the misinformation.

What do I mean by a “weakened form of misinformation”? An inoculating message consists of two elements: warning people of the threat of being misled—which is important in putting people on guard against the danger of misleading persuasion—and then providing counterarguments explaining how the misinformation is wrong. In an extension of the experiment

described above with the climate consensus and misinformation, there was an inoculation that explained the different ways that the Global Warming Petition Project was misleading.⁵ First, it was an online petition with little quality control, resulting in Star Wars characters and Spice Girls appearing on the list of signatories. Second, while 31,000 seems like a large number, it's a tiny fraction of the millions of Americans with degrees in science. Lastly, while it lists people with all types of science degrees, such as computer scientists, medical scientists, and engineers, less than 1 percent of the signers have expertise in climate science. When participants in the experiment were inoculated before being shown the misinformation, the facts had a positive effect and the misinformation was mostly neutralized. Crucially, this held true for Democrats, Republicans, and Independents; the results for Republicans were especially heartening because other facets of the study indicated that they were, on average, predisposed to believe the misinformation.

An inoculating message consists of warning of the threat of being misled and then explaining how the misinformation is wrong.

Around the same time that this research was happening, my colleagues and I were conducting similar research, also testing how to inoculate people against climate misinformation.⁶ Coincidentally, we even used the same misinformation: the Global Warming Petition Project. Overall, our results were similar, showing that people at the conservative end of the political spectrum were strongly influenced by misinformation, while people who were politically liberal were relatively unaffected—and also showing that inoculation can be effective. Notably, we used a different inoculation technique. Before being given the misinformation, one group in our study learned about fake experts. This is where a person appeals to their own expertise and yet doesn't have *relevant* expertise. Fake experts are frequently deployed to confuse the public and can be highly persuasive. Fortunately, our general inoculation against fake experts completely neutralized the misinformation and, importantly, was effective across the political spectrum. This tells us that whether people are politically conservative or liberal, no one likes being misled.

Facts or Logic? Yes!

My research has focused on two main types of inoculation: fact based and logic based.⁷ Fact-based corrections explain how the misinformation is false or misleading. For example, you can show how the myth “we should emit CO₂ because it's good for plants” is misleading by explaining the various factors plants need to flourish, such as a regular water supply and comfortable temperature range. Emitting CO₂ causes climate change, which disrupts these conditions.

Logic-based corrections involve explaining the rhetorical techniques or logical fallacies used in misinformation. For example, you can explain how the “CO₂ is plant food” myth uses the fallacy of oversimplification. By focusing on a single factor like CO₂ fertilization, it ignores other factors that plants need to grow. This myth is like arguing “our bodies need calcium, so all we need to eat is ice cream,” despite the fact that our bodies need a balanced diet.

Both of these approaches are effective.⁸ Whenever possible, I try to use both in combination—explain the facts, introduce the myth, and then reconcile the conflict between the two by explaining the myth's fallacy. This fact-myth-fallacy format is the recommended structure for debunking (or *prebunking*) laid out in *The Debunking Handbook 2020* (which is available for free in multiple languages at sks.to/db2020).

Although factual corrections are often crucial, the logic-based approach offers some unique benefits. Explaining the rhetorical technique used in one topic can help build resistance to the same technique used in a different topic. For example, consider the two inoculations described above for the Global Warming Petition Project. Pointing out that many of the signatories are computer scientists and not climate scientists is a factual correction that applies to the petition. Highlighting that such fake experts are widely used to intentionally mislead puts people on guard for the petition and for other situations in which claims rely on “experts.” In our research, my colleagues and I explained how tobacco companies used the fake expert strategy* to cast doubt on the scientific evidence linking smoking to negative health impacts.⁹ When people were subsequently shown misinformation about climate change using the same fake expert technique, the misinformation no longer had an impact. Logic-based inoculation conveys immunity across topics—it's like a universal vaccine against misinformation.[†]

In a different experiment, my colleagues and I directly compared the logic-based and fact-based approaches in addressing the climate myth that we should emit more carbon dioxide because it's plant food.¹⁰ We also tested whether order mattered when encountering misinformation and corrections. We asked whether debunking—seeing the correction *after* the misinformation—had a different effect than prebunking—seeing the correction *before* the misinformation. When people were shown the logic-based correction, it reduced belief in the myth regardless of whether it came as a prebunking or a debunking. Order didn't matter with the logic-based correction. But with the fact-based correction, order did matter: prebunking did not work. If the fact-based correction was the last thing people were shown, the myth was successfully debunked. But if the misinformation was the last thing people read, the myth cancelled out the facts. This underscores the inherent danger of misinformation and its ability to cancel out our factual explanations—especially since, in the real world, people see a mix of facts and myths regularly.

*To learn more about how tobacco companies have intentionally misled the public, see “Mercenary Science: A Field Guide to Recognizing Scientific Disinformation” on page 20.

†My colleagues and I have not yet been able to conduct studies to determine how long this inoculation may last. Generally, the research shows inoculation effects fade over time, so “booster shots” are required; it also shows logic-based inoculations last longer than factual explanations.

The bottom line is that communicating both the facts and the rhetorical techniques used to cast doubt on facts is important. In practice, I try to incorporate both. But the unique benefits of logic-based corrections are crucially important; to prevent misinformation from spreading, raising awareness of the logical fallacies and rhetorical techniques used to intentionally mislead is imperative.

Giving Misinformation the FLICC

In order to explain misleading techniques, it helps to have a vocabulary to describe them. I've explored different ways of organizing and explaining misinformation techniques, but I've always come back to FLICC: fake experts, logical fallacies, impossible expectations, cherry picking, and conspiracy theories.¹¹ Over the years, I've expanded these five categories into an ever-growing taxonomy (shown on page 16) of rhetorical techniques, logical fallacies, and conspiratorial traits.¹²

Along with documenting the landscape of misinformation techniques, I've also explored approaches to more effectively explain them to the public. One powerful approach is *parallel argumentation*, which involves transplanting the flawed logic from a fallacious argument into an analogous situation (e.g., I used this strategy above to clarify that just as humans need more than ice cream, plants need more than CO₂).¹³ Parallel arguments have strong pedagogical value, allowing educators to explain abstract logical concepts in concrete terms, typically using examples from everyday life.¹⁴ One key benefit—particularly for students who are just beginning to learn science—is that by focusing on errors in reasoning, we can show how misinformation is misleading while sidestepping the need to provide complicated explanations that rely on extensive science knowledge.

Parallel argumentation is also conducive to attention-grabbing and humorous applications. Through several studies, my col-

leagues and I have found cartoons with parallel arguments are effective in debunking misinformation about vaccines¹⁵ and climate change.¹⁶ Using eye-tracking data, we found humorous cartoons successful in discrediting misinformation because people spent more time paying attention to the cartoons than to corrections delivered in other, less engaging ways.¹⁷ As a bonus, humorous corrections were more likely to be shared, increasing their chances of going viral. (The most viral tweet I ever posted, reaching several million impressions, was a cartoon debunking COVID-19 misinformation; it is shown on page 17.)

The reality that our factual explanations are vulnerable to misinformation highlights the importance of logic-based corrections. It's like shielding our factual explanations with protective bubble wrap as we send them out into a cold, hard world. And it turns out that the classroom is the ideal venue for building resilience against misinformation.

Inoculation in the Classroom

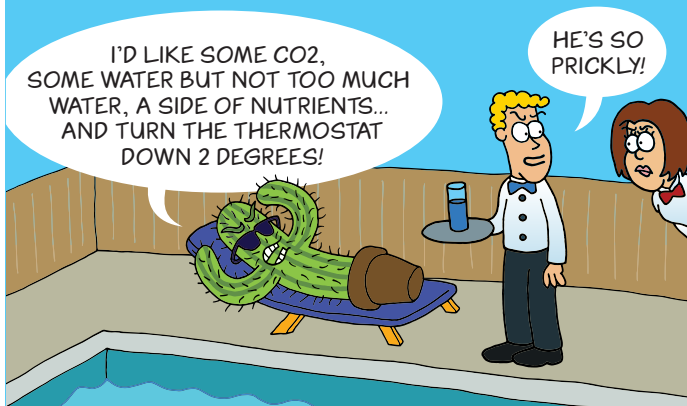
How does inoculation work in an educational context? There is a teaching approach known as *refutational teaching* or *agnotology-based learning* (I personally refer to it as *misconception-based*

Logic-based inoculation conveys immunity across topics—it's like a universal vaccine against misinformation.

Fact-Based Correction

Debunking the myth "CO₂ is plant food"

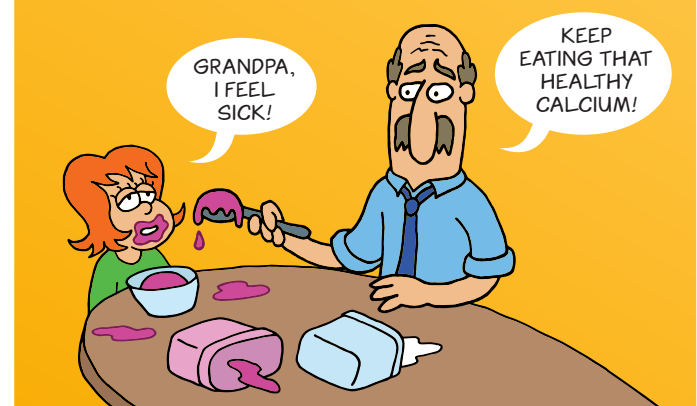
Climate change caused by CO₂ results in heat waves and increased flooding. While plants do use CO₂ to grow, CO₂ emissions ultimately harm plant growth. Plants are fussy—they need a comfortable temperature range and the right amount of water to flourish.



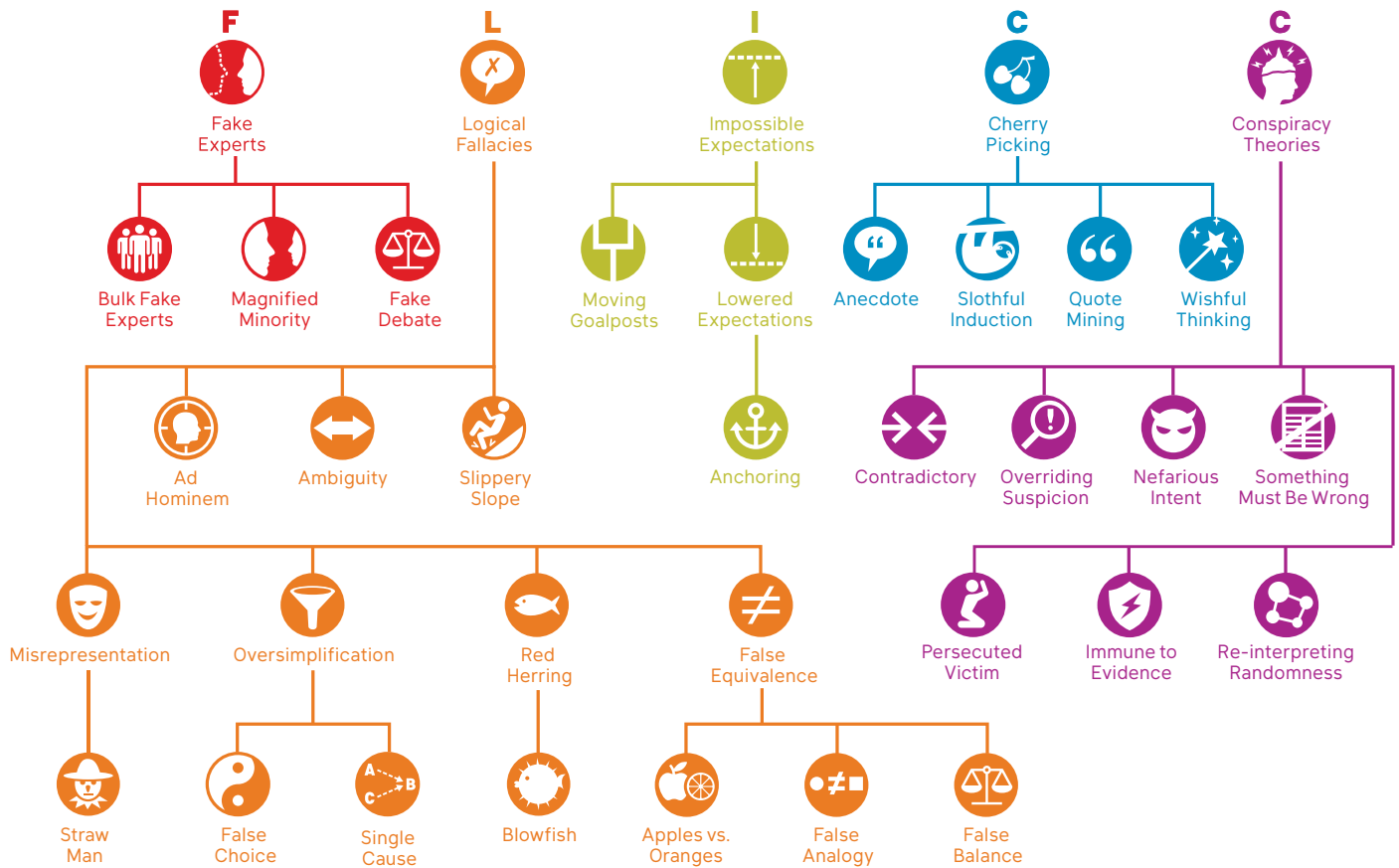
Logic-Based Correction

Debunking the myth "CO₂ is plant food"

Climate change caused by CO₂ disrupts the environment, with heat stress and increased flooding harming plant growth. This myth is an oversimplification—it's like saying humans need calcium so all we need to eat is ice cream.



The FLICC Taxonomy organizes the five categories of intentional misinformation techniques and the various fallacies and rhetorical techniques within each category. For more details, see crankyuncle.com/a-history-of-flicc-the-5-techniques-of-science-denial.



learning). This approach involves teaching science by directly tackling scientific misconceptions. For example, one can explain the carbon cycle by addressing how the phenomenon might be misunderstood. Every year, vast amounts of carbon move through our climate system. In the fall, plants give up billions of metric tons of carbon dioxide into the atmosphere as leaves fall and decompose. In the spring, plants absorb the carbon dioxide back from the air as leaves grow back. This system is balanced, with the amount of carbon absorbed during the spring roughly equal to the amount of carbon released during the fall.

One myth about climate change is that human CO₂ emissions don't matter because they're tiny compared with natural CO₂ emissions. After all, we emit around 30 billion metric tons per year, while nature emits over 700 billion metric tons every year. This myth ignores that nature is roughly in balance, with natural absorptions matching natural emissions.¹⁸ Our CO₂ emissions disrupt the natural balance, resulting in atmospheric CO₂ increasing to levels not seen in millions of years. By directly addressing the myth, we not only address a misconception about the carbon cycle but also deepen our understanding of how human activity has disrupted the natural balance.

Misconception-based learning is one of the most powerful ways of teaching science. It's been shown to result in higher learning gains, and, importantly, the gains last longer relative to standard lessons.¹⁹ Students find misconception-based learning more

engaging,²⁰ and it appears to have the curious benefit of instilling appropriate humility. One study compared the effect of standard lessons versus misconception-based lessons, finding that students made stronger learning gains from the misconception-based lessons²¹—but students who received the standard lessons were more confident of their understanding (despite recording lower learning gains). Unfounded confidence can be a roadblock to learning, and misconception-based learning reduces that barrier.

Unfortunately, there is a dearth of educational resources to help teachers apply misconception-based learning. Over the last decade, I've been working on developing resources in a number of different contexts to address this deficit. For high school educators, I collaborated with the National Center for Science Education to develop a curriculum teaching fundamental concepts of climate science while addressing common myths and misconceptions about climate change.* For college professors, I coauthored a climate textbook with Weber State University's Dan Bedford in which each chapter not only explains key concepts regarding climate change but also debunks common myths associated with them.²² And in a more informal learning context, I led a collaboration between the online learning team at the University of Queensland and the team of climate misinformation debunkers at Skeptical

*To download this free curriculum, visit ncse.ngo/supporting-teachers/classroom-resources.

Science to develop a massive open online course, “Making Sense of Climate Science Denial.”[†] This course features around 50 short videos explaining the facts of climate change as well as debunking related myths and exposing the logical fallacies in each myth.

The purpose of misconception-based learning is to improve students’ science literacy and boost their critical-thinking skills. But in recent years, a new approach to inoculation has emerged that may offer an even more engaging and interactive way to neutralize misinformation.

Gamifying Critical Thinking to Build Resilience

Most examples of inoculation against misinformation are what researchers describe as *passive* inoculation—one-way communication where the audience passively receives the inoculating message. But an exciting new approach is *active* inoculation. This involves learning the techniques of misinformation by actively employing them. Active inoculation can be applied in a number of ways, particularly in the classroom; for example, students could do role-playing exercises or purposely attempt to incorporate misleading techniques in their writing.

Among those of us who study inoculation, there’s been an increasing focus on digital games, which are a particularly engaging and scalable approach. Generally speaking, games that are designed to be both fun and educational are known as *serious games*.²³ In the last few years, a growing number of serious games have focused on building resilience against misinformation through active inoculation.

The Bad News game is an early example of this approach, where the goal of the game is to become a fake news merchant. Through the course of the game, players learn about six techniques of fake news, such as emotive posts or impersonating authoritative sources. Preliminary evidence indicates that by the end, players have become somewhat more aware of and resistant to misinformation.²⁴ The Bad News game focuses on media literacy, so that players become better able to assess the reliability of online information sources such as news websites and Twitter accounts. New games adapting the Bad News game template have

[†]To take this free course, visit edx.org/course/making-sense-of-climate-science-denial.

also focused on misinformation undermining democracy²⁵ and COVID-19 misinformation.²⁶

While media literacy is an important skill for students to develop, critical thinking is a broad umbrella. As well as assessing media sources, students also need to be able to assess arguments, whether on social media, on mainstream media, or in conversation. Over the last few years, I’ve been working with Autonomy Co-op to develop a game that teaches players how to spot misleading rhetorical techniques—the kinds of fallacious arguments we might hear from our cranky uncle.

By adopting the mindset of a cranky uncle, players develop a deeper understanding of science denial techniques.

Getting Cranky to Stop Misinformation

The Cranky Uncle game (available for free at crankyuncle.com/game) is designed to build resilience against the techniques of science denial. The player’s goal is to become a science-denying “cranky uncle” by learning about a range of misleading rhetorical techniques used to reject the conclusions of the scientific community. By adopting the mindset of a cranky uncle—inspired by the active inoculation approach—players develop a deeper understanding of science denial techniques. Although I intend to conduct several more studies to determine the effectiveness of the game and improve it, preliminary results show increases in critical thinking. Ultimately, the intent is to inoculate players against misleading persuasion attempts in the future.

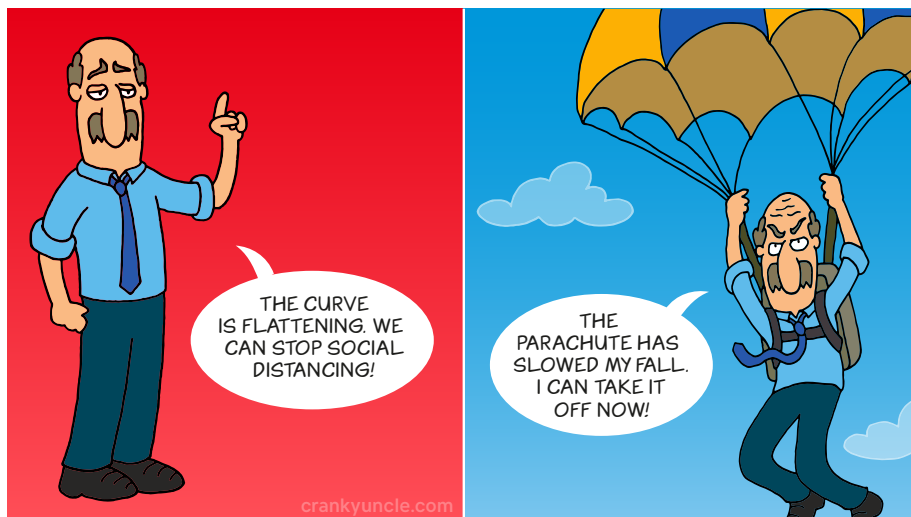
The game consists of two elements. First, Cranky Uncle explains the techniques of science denial. This includes the five categories of FLICC as well as many of the fallacies and techniques found in the FLICC taxonomy.

But this brings us to a fundamental psychological challenge when trying to build resilience against misinformation. Critical thinking is hard! Our brains are hardwired to make fast, snap decisions rather than slowly reason through problems.*

However, there is a way to make critical thinking faster and less difficult: mastering expert heuristics. When a person practices a difficult task over and over, the slow thinking processes required to complete the difficult task gradually evolve into fast thinking responses. For example,

*To learn about how our minds work and why critical thinking requires so much effort, see “Why Don’t Students Like School? Because the Mind Is Not Designed for Thinking” in the Summer 2009 issue of *American Educator*: go.aft.org/3o2.

The most viral tweet I’ve ever posted.



Explanations of the Techniques of Science Denial

(a) Denial techniques. (b, c) Explanation of conspiracy theories. (d) Feedback after completing the explanation.



Educators are in a unique and powerful position in the fight against misinformation.

consider the difference between teenagers who are learning to drive—struggling to signal a turn, check the rear view, and lightly press the break just to go around the block—and an adult who hops in the car and runs errands virtually on autopilot. With enough practice, even very complex mental tasks can become easy. This is where games offer a potential solution to building resilience against misinformation.

The second feature of the Cranky Uncle game is quizzes in which players try to spot fallacies in examples of misinformation. Their purpose is to use gameplay elements such as collecting points and moving to higher levels to motivate players to practice critical thinking, *over and over again*. The more quizzes completed, the quicker and easier it gets to spot common patterns in deceptive arguments. For example, the *false-choice fallacy*, otherwise known as a *false dichotomy*, is widely used in misinformation. The tell-tale red flag for this argument is being presented with an either-or choice. When you see that form of argument, consider whether other options might be available besides the two presented (or perhaps both options could be true at the same time).

The game approach does have some limitations. For example, spotting the technique of cherry picking can be difficult if you don't have enough relevant background knowledge. But even in this case, the game helps players spot one common form of cherry picking known as *anecdotal thinking*. This powerful form of misinformation uses compelling narratives and can be quite persuasive. But if players learn how to spot the use of single examples (i.e., anecdotes) as evidence for an argument, they likely will become less vulnerable to being misled by that form of cherry picking.

The danger of serious games is players can lose interest in playing the game if they see it as no fun and all education. Fun is one of the main factors determining whether players are willing to play a game again.²⁷ By featuring an ornery cartoon character as the player's mentor guiding them through the game, as well as humorous examples of logical fallacies in the quizzes, I hope this pitfall is avoided for most youth playing Cranky Uncle. In the Cranky Uncle game, humor is an integral part of the learning process, with parallel arguments in cartoon form providing not only humor but also instructive illustrations of fallacious logic. This makes the game an engaging tool for the classroom, afterschool clubs, and summer programs.

By October 2021, just 10 months since the Cranky Uncle game was released, educators have signed up to use the game in over 38 U.S. states (as well as 16 other countries)—in both red and blue states—which gives me hope that the game is reaching communities across the political spectrum. Further, the game is being adopted in a range of subjects as diverse as biology, environmental science, English, media studies, and philosophy. This demonstrates the growing conviction that critical thinking is needed in any subject where misinformation can be found (i.e., all subjects). The other intriguing element of the game is to see

Examples of Quiz Questions and Achievement Notification

(a) True/false question. (b) Selecting a specific myth from multiple examples. (c) Selecting a fallacy from a cartoon example. (d) Notification when a player achieves a higher level.



it being adopted in classes from middle school to graduate school (it's even in a few elementary classes). My colleagues and I are in the process of collecting data to assess the game's effectiveness at different levels.

In the classroom, an activity that seems beneficial after students have played the game several times is to role-play. When giving guest lectures in college classes on climate change, I have played the cranky uncle while the professor tries to convince me of climate change. After this demonstration, we divide the class into small groups and the students conduct their own role-play exercises. Afterward, students often discuss how much easier it is to be the cranky uncle and how difficult it is to respond to fallacious arguments in real time.

Misinformation is an immense societal problem—ever present and ubiquitous. This necessitates solutions that can reach significant proportions of the population at a scale commensurate with the problem. But further, misinformation is complex and interconnected—with cultural, psychological, and technological factors. This complexity means we need holistic solutions. I'm convinced we need interdisciplinary solutions that combine science, technology, and the arts. Science provides evidence-based approaches to addressing misinformation, such as logic-based inoculation. Art can help package educational material in engaging, memorable formats. Technology allows the development of games that are both interactive and scalable.

The Cranky Uncle game brings together these diverse threads, synthesizing research on inoculation, critical thinking, and science humor, wrapped in a technological package that is accessible and interactive. But there is no magic bullet that will neutralize the mis-

information problem. This is a multi-front struggle, requiring public campaigns and technical solutions implemented in collaboration with social media platforms. Nevertheless, educators are in a unique and powerful position in the fight against misinformation. □

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Mercenary Science

A Field Guide to Recognizing Scientific Disinformation



By David Michaels

Johnson & Johnson (J&J) has long insisted that Johnson's Baby Powder, its iconic brand of talcum powder, is safe to use. However, its primary ingredient, talc, is often mined from mineral deposits that also have asbestos-like fibers. In October 2019, the firm announced the recall of 33,000 bottles of Johnson's Baby Powder after the US Food and Drug Administration (FDA) found a sample contaminated with asbestos; a few months later, J&J stopped selling talc-based baby powder in North America altogether. J&J never warned consumers that using its product might risk asbestos exposure (and therefore cancer). It avoided that warning through some maneuvers that came right out of the playbook developed decades ago by many of the biggest companies in the tobacco industry.

Twenty-one years ago, studies finding asbestos-related disease in workers and animals exposed to talc led the Board of Scientific

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Counselors of the US National Toxicology Program* to consider labeling talcum powder contaminated with asbestos-like fibers as cancer causing. Recognizing this could devastate sales, J&J and other firms that mined or used talc hired consultants to question the studies the National Toxicology Program had reviewed. Some of these consultants had worked for the tobacco industry and had devised various ways to question the research linking smoking to lung cancer and other diseases. With talc, they deployed a similar strategy; their objective was to create enough uncertainty that the National Toxicology Program scientists would be unable to conclude exposure to talc products was potentially deadly.

"Time to come up with more confusion!" This bold declaration was in an internal memo describing the consultants' talc campaign.¹ In the short run, the strategy worked. The National Toxicology Program dropped the proposed warning in 2005 and has never returned to it.

The longer-term consequences, however, have been enormous. In recent years, the evidence linking exposure to talcum powder with ovarian cancer has increased, and thousands of women have sued J&J, alleging its product caused their illnesses. In one of the first cases, 22 women with ovarian cancer were awarded more than \$4 billion in punitive damages. (The award,

*Disclosure: from 2011 to 2017, I was the chair of the National Toxicology Program's Executive Committee, and I am now a member of its Board of Scientific Counselors.

which was reduced to \$2.1 billion, was recently upheld by the US Supreme Court; J&J is now attempting to protect itself by spinning off its talc-related liabilities into a new corporation that promptly declared bankruptcy.) The jurors, having read the memos describing the efforts to manufacture uncertainty as well as to disproportionately market the product in communities of color, were sending a loud message to J&J and other corporations that intentionally obscuring the harms of a product was not acceptable behavior.

The talcum powder industry's response to the government's attempt to protect American consumers was not unique. In fact, that strategy of creating confusion and doubt, often called the *tobacco playbook* after the industry that used it so successfully, has become standard operating procedure among many corporations across a wide range of industries.

The Tobacco Playbook

Big Tobacco's campaign to manufacture uncertainty to defend a dangerous product is the most well-known of these efforts. That industry's drive to cause confusion and uncertainty is famously summarized in the memo penned by a tobacco executive: "Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the minds of the general public. It is also the means of establishing a controversy."²

The tobacco industry's success has contributed to the premature deaths of many millions of smokers across the globe. One of the playbook's chief strategies, paying public relations professionals and scientific experts to question the evidence, is now marketed by "product defense" specialists and used widely by firms eager to avoid addressing the harms caused by their products. Their campaigns are often very sophisticated and go well beyond simple public relations. To convince regulators, jurors, the press, and the public that the science is uncertain, firms often sponsor studies with preordained conclusions and publish them in what appear to be credible scientific journals.

I have witnessed up close how corporations have applied the tobacco playbook by commissioning product defense scientists to fight public health protections. In 1998, I took a leave of absence from the City College of New York, where I was a member of AFT Local 2334, the Professional Staff Congress, to serve as President Bill Clinton's assistant secretary of energy for environment, safety, and health. My responsibility was protecting the workers, community residents, and environment in and around the nation's nuclear weapons complex. These facilities had harbored—and in some cases still do harbor—huge amounts of the toxic chemicals required to make the plutonium and highly enriched uranium at the core of nuclear weapons. Manufacturing and testing these weapons almost necessarily exposed thousands of workers to chemicals and radiation and created some of the most dangerously polluted locations in the country.

One of the most toxic chemicals to which these workers were exposed was beryllium, a metal used to help maximize the power of an atomic explosion. Exposure to small amounts of beryllium can cause disabling lung damage. Under my leadership, we issued a series of new safety and health regulations, including a strengthened beryllium exposure standard. Of course, we had to overcome the efforts of the beryllium industry, which engaged a product

defense firm (with a long history of defending tobacco) to convince the US Department of Energy that there was too much uncertainty to move forward with the stricter standard.³

With the end of the Clinton administration, I returned to teaching, this time at the George Washington University School of Public Health. Through further research, I learned that creating doubt about the science underpinning public health protections had become standard operating procedure for many producers of all sorts of harmful products. Outraged by this behavior and wanting others to see how science was being abused, I wrote my first book on the subject, *Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health*.⁴

"Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the minds of the general public."

—A tobacco executive

I had not planned to go back into government service, but President Barack Obama asked me to serve as assistant secretary of labor for the Occupational Safety and Health Administration (OSHA), which is the most important position in the area of worker safety and health in the nation. One of my many responsibilities at OSHA was standard setting, and I was back to tangling with corporations that wanted to put profits above health.

My staff and I worked hard to strengthen the standard for workplace exposure to silica, a dust that can cause silicosis (a lung disease) or lung cancer. Of course, our efforts were met with opposition by related industries and their product defense firms. Under President Obama, we were able to make real progress in defending the science underpinning our silica standard, and the industry's attempts to stop it were unsuccessful. But the election of Donald Trump to the presidency set back those efforts and inspired me (so to speak) to return to teaching at George Washington and to my previous focus on the product defense industry and mercenary science, with its deleterious impact on the nation's health and environment. The outcome was a second book, *The Triumph of Doubt: Dark Money and the Science of Deception*.⁵

Although the Trump administration is now in the rearview mirror, the tobacco playbook continues to serve as the template for the behavior of too many businesses. Dark money rules as corporations and rich individuals fund organizations set up as "educational" nonprofits whose objective is to sow confusion



and uncertainty on everything from climate change to toxic chemicals to the health impacts of sugar-sweetened sodas and alcoholic beverages.

The tobacco playbook has been widely applied, generally with great success—if “success” is measured by delaying action to protect the public. Here are just a few recent examples. Until the discovery of the “defeat devices” that fooled auto emissions testing systems into mismeasuring cars’ diesel engine exhaust, Volkswagen bankrolled efforts to dispute studies that documented the deleterious impact of diesel pollution on human health.⁶ Battery manufacturers and smelters employ consultants to question studies on the impact on children of low levels of lead exposure.⁷ ExxonMobil and the oil industry pay many of these same consultants to claim that the evidence of the health effects of air pollutants like ozone is too uncertain to use in setting regulatory limits.⁸ Years ago, scientists at these same fossil fuel firms actually modeled the impact of atmospheric carbon accumulation and pre-

The corporations market their studies as “sound science,” but in reality, they merely *sound like* science.

dicted much of the extreme climate we are experiencing today, but that didn’t stop their firms from funding the climate change denial machine (which has many leaders who previously did similar work for the tobacco industry).⁹ Even the National Football League, following initial reports of concussion-related brain injury among its players, took the tobacco road. It appointed a committee stacked with members with financial ties to the teams, and the committee did its best to discredit the accumulating evidence, enabling the league to delay addressing the problem for a decade.¹⁰

At the center of this confusion and doubt are product defense consulting firms. These operations have on their payrolls toxicologists, epidemiologists, biostatisticians, risk assessors, and any other professionally trained, media-savvy experts deemed necessary.* Much of their work involves developing scientific materials that purport to show that a product a corporation makes or uses or discharges as air or water pollution is not very dangerous. These “experts” produce impressive-looking reports and publish the results of their studies in supposedly peer-reviewed scientific journals (reviewed, of course, by peers of those writing the articles,

*For example, economists are useful for inflating the costs and deflating the benefits of proposed regulation, as well as for antitrust issues.

not independent scholars). Simply put, the product defense machine cooks the books, and if the first recipe doesn’t pan out with the desired results, they commission a new effort and try again. Since confusion and doubt are the goals, churning out a large volume of low-quality studies is in itself a “success.”

The product defense ploy is public relations disguised as science. Companies’ PR experts provide these scientists with contrarian sound bites that play well with reporters who believe there must be two sides to every story and that both sides are equally worthy of fair-minded consideration. The scientists are deployed to influence regulatory agencies that are tasked with protecting the public or to defend against lawsuits by people who believe they were hurt by the product in question. The corporations and their hired experts market their studies and reports as “sound science,” but in reality, they merely *sound like* science. Corporate leaders venerate such bought-and-paid-for research, while vilifying any academic research that might threaten corporate interests.

Since their specialty is the manufacture of doubt, they can apply their tools in almost any field, to almost any product. The result is always the same: questioning or downplaying the negative health effects of their sponsor’s product. The result is predictable because this is the business model of the firm; if the firm produced reports finding the sponsor’s product was dangerous and needed to be regulated closely, it would get no more work from corporations who need their products exonerated.

It is easy to identify some of the major firms currently active in the product defense industry by searching two archives: Toxic Docs, a repository of documents managed by Columbia Uni-

versity and the City University of New York,¹¹ and the University of California San Francisco’s Industry Documents Library archive,¹² which includes millions of pages disgorged by the tobacco industry as a result of lawsuits. These lawsuits demonstrated that cigarette manufacturers violated racketeering laws, having conspired for decades to defraud the public about the health risks associated with smoking. Both of these archives are filled with contracts and memos describing the work of scientists employed by several product defense firms: Exponent (including work for tobacco under its previous name “Failure Associates”), Ramboll (when it was called “Environ”), Cardno ChemRisk (when it was just “ChemRisk”), Gradient, and other smaller firms.

Whether in regard to consumer products, pesticides, heavy metals, or air or water pollution, the same firms appear over and over again in efforts to slow attempts by the US Environmental Protection Agency or OSHA to protect the public’s health. Wealthy industries facing regulations that would dampen their profits often hire several firms. For example, attempting to dispute studies documenting the link between diesel engine emissions and lung cancer, the oil industry and some engine manufacturers hired Gradient,¹³ Ramboll,¹⁴ and Exponent.¹⁵ And at least three firms—Gradient,¹⁶ Exponent,¹⁷ and ChemRisk¹⁸—were employed by DuPont or 3M to defend cancer-causing PFAS compounds, the “forever chemicals”



used in Teflon and firefighting foam, that have polluted hundreds of water systems across the country.

Doesn't Science Have Safeguards?

Science, in its pure form at least, is about asking questions, designing experiments, and scrutinizing the evidence to find answers. Only a small portion of the studies examining harm from exposure to products or pollutants is done by product defense scientists. More often, such studies are undertaken by university-based scientists, who are required to raise outside funding to pay for all or part of their salaries, as well as the operation of their laboratories. As a result, a significant portion of the research in toxicology published in academic journals is produced with corporate funding.

Not surprisingly, no matter who performs the study, the studies paid for by a private sponsor tend to deliver the results the sponsor wants. Researchers know this as the “funding effect” or, maybe more cynically, the Golden Rule: those who have the gold make the rules. There have been so many studies documenting the funding effect in evaluating risks (or in some cases, identifying benefits) associated with medications, tobacco, food products, chemicals, and pollutants that it is almost surprising when manufacturers of a product sponsor a study that does not find the results they desire.

Interestingly, these may not be rigged studies. Not wanting to threaten their funding stream, researchers, consciously or not, design studies hoping to find the results most favorable to their sponsors. Study results can be easily influenced by choices researchers have to make, including outcomes measured, the comparisons made, the length of time studied, and a host of other factors.¹⁹

We know the impact of the funding effect because, for many studies, the authors disclose who paid for their work—and researchers have documented a strong relationship between funders' desires and studies' outcomes. (However, as discussed below, there are still plenty of studies with incomplete or misleading disclosures.) Disclosure of a conflict of interest is important, but not as important as the conflict itself. The disclosure figures into the assessment of the scientific research as published, but the conflict shapes the course of the research. It is a huge difference, and one that's easily forgotten.

Some scientists will say pretty much whatever someone pays them to say. But the broader “conflict” issue is much more nuanced, and it affects all scientists (and all people). Theoretically, a scientist conducting an experiment and following certain accepted methods will find the same results as anyone else who does the same experiment the same way. That's the theory. In most laboratory experiments, however, the investigator must make many decisions along the way that can shape the outcome. All of these decisions can be influenced by their prior beliefs (a perhaps kinder way of saying “prejudices”), theories, and experiences. Another label for this dynamic is “motivated reasoning.” The funding source for any research—who's footing the bill—is a powerful motivator of anyone's reasoning. Any of us would look at the same data differently than someone with a different set of financial relationships.

Further, it is difficult for most of us to acknowledge that something we do causes harm, and confirmation bias helps us miss

even the most obvious harms. There is a famous natural experiment supporting this point. Twenty years ago, well-regarded academic cardiology experts associated with Merck & Co., which made the painkiller Vioxx, misinterpreted data comparing heart attack rates among patients who took Vioxx with rates among those who took naproxen (sold over the counter as Aleve). There were two ways this randomized clinical trial's results could be interpreted: Vioxx more than doubled heart attack risk or naproxen lowered it by more than 50 percent. The scientists paid by Merck chose the latter,²⁰ even though there is no drug known to be anywhere near that effective in reducing heart attack risk.

Not long afterward, the truth became known: a different study that compared Vioxx to a placebo confirmed that Vioxx greatly increased heart attack risk. Even before this study was completed, the results were so compelling that Merck voluntarily withdrew Vioxx from the market. FDA scientists estimated that in the four years the drug was on the market, it had caused between 88,000 and 140,000 heart attacks.²¹ How did respected university-based cardiology experts get it so wrong? As Upton Sinclair famously said, “It is difficult to get a man to understand something when his salary depends upon his not understanding it.”

Not surprisingly, studies paid for by a private sponsor tend to deliver the results the sponsor wants.

We need a system that develops the relevant scientific evidence before people are harmed and lawsuits are launched. Firms whose products may be harmful should be required to fund the studies necessary to evaluate those concerns. However, for the studies to be credible, the funders should have no role in developing the research agenda, choosing the investigators or methods used, or reporting the results. This is the only way to wrest back truth, restore faith in the process of using science to safeguard public health, and protect generations to come.

In the meantime, greater public awareness of product defense and its confusion and doubt tactics will make it more difficult for polluters and manufacturers of dangerous products to continue to harm the public's health.

Recognizing Mercenary Studies

What follows is a field guide for teachers and students of science to the tricks used to manufacture and sell scientific disinformation.



The Strategic Literature Review

One popular tactic—maybe the most popular—is some version of “reviewing the literature.” The basic idea is valid; we *do* need to consider the scientific studies to date to attempt to answer important questions. The questions that come up in regulation and litigation are complex; they go way beyond simply asking, “Does this chemical cause cancer or lower sperm count or cause developmental damage?” With public health issues, the important and tricky part is determining at what level an exposure can contribute to the undesired effect, and after how much time and exposure. Is there a safe level of exposure, below which a chemical cannot cause disease (or has not caused disease, in the case of litigation)? No single study answers such questions, so reviews are warranted.

It is easy enough to design an alternative analysis that will make unwanted results disappear.

Sometimes these literature reviews are labeled “weight-of-the-evidence” analyses, in which the authors decide how much importance to give each study. But if their business model—their whole enterprise—is based on being paid by the manufacturers of the product in question for those reviews, their judgment is suspect. How can you know whether the weight they have assigned different studies, intentionally or unconsciously, is impacted by the fact that their sponsors want a certain result? If a review was undertaken by conflicted scientists in business to provide conclusions needed by a commercial sponsor to delay regulation or defeat litigation, the findings are tainted and should be discarded.

The Mercenary Risk Assessment

Weight-of-the-evidence reviews generally include both human and animal studies, and the attribution of weight to any given study is generally a subjective, qualitative decision. A more quantitative approach to reviewing the literature entails so-called risk assessment, which in its earnest form attempts to provide estimates of the likelihood of effects at different exposure levels. Importantly, risk assessments attempt to estimate the levels below which exposure to a given substance will cause no harm.

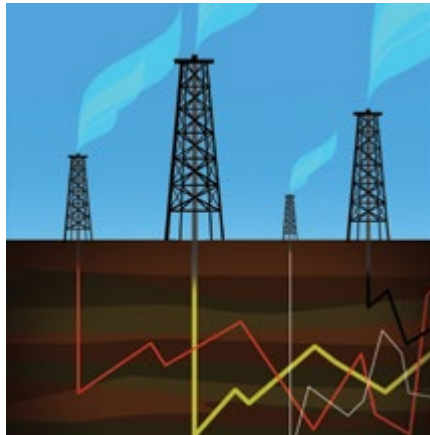
This much is true: there is tremendous variation in the results of many risk assessments. There are also individual scientists and firms who can be counted on to produce risk assessments that, conveniently for their sponsors, find significant risk only at levels far above the levels where most exposures are occurring. And if these risk assessments are accepted by regulatory agencies or

jurors, the sponsors will be required to spend far less money cleaning up their pollution or compensating victims.

The Rigged Reanalysis

By its nature, epidemiology is a sitting duck for the product defense industry’s uncertainty campaigns. Epidemiologic studies are complicated and often require complex statistical analyses. Judgment is called for at every step along the way, so good intentions are paramount (as is the absence of a financial interest in the outcome). Epidemiologic principles and ethics require that the methods of analysis be selected before the data are actually analyzed. One tactic used by some product defense firms is the reanalysis, where the raw data from a completed study are looked at again, changing the way the data are analyzed, often in the most mercenary of ways.

The battle for the integrity of science is rooted in these sorts of issues around methodology. If a scientist with a certain methodological and statistical skill set knows the original outcome and how the data are distributed within the study, it is easy enough to design an alternative analysis that will make unwanted results disappear. This is especially true with findings that link a toxic exposure to disease later on—which also happen to be among the most important results for public health agencies. This tactic was used by ChemRisk when it was hired by the American Petroleum



Institute after scientists at the National Institute for Occupational Safety and Health (NIOSH) found that low levels of exposure to benzene increased leukemia risk. To discredit the study, the industry-affiliated scientists contended NIOSH had underestimated historic workplace benzene exposure levels, so they came up with new estimates, and produced a new study purporting to show that only much higher exposure levels caused disease. Unfortunately for the oil industry and its scientists, it was pointed out that the new estimates were so high, they would have poisoned many of the workers, so the new study was quickly discarded.²²

As with most things about product defense, the reanalysis strategy dates back to the tobacco industry, whose strategists recognized that they needed a means to counter early findings related to smoking’s dangers in order to shirk responsibility and regulation for lung cancer risk among nonsmoking spouses of smokers. From a public health perspective, one early finding—a 25 percent increase in cancer risk—was a big deal. To the industry, making it disappear would be a huge deal. Industry strategists and scientists, realizing that they couldn’t mount their own studies quickly enough, figured they could get the raw data from the incriminating studies, change some of the basic assumptions, alter the parameters, tinker with this and that, and make the results go away. Tobacco’s approach is now commonplace; “reanalysis” is its own cottage industry within product defense.

The “Independence” Gambit

Many papers produced by product defense firms contain the disclosure that individual scientists may be testifying for corporations

that are being sued, but that the research itself was done *independently* of the corporations. This sleight of hand provides a fiction of independence in order to give the illusion of objectivity, but the research was almost certainly paid for by the product defense firm out of fees paid by the corporation. Sometimes the fiction of independence is created by omitting crucial information. For example, when Georgia-Pacific (GP) was funding studies with the goal of reducing its asbestos exposure liabilities, one study author noted a grant from GP while his coauthor neglected to mention being a GP employee whose work was directed by a GP lawyer.²³ Such independence is a charade, but it is also standard practice.

Front Groups

A different kind of conflict of interest, and a different kind of disclosure trickery, is the use of front groups by many industries to advance their interests while hiding their involvement. These fronts are generally incorporated as not-for-profits with innocuous-sounding names and physicians or academic scientists in leadership positions. But they are paid for by their various corporate sponsors, many of them funding “research” to be used in regulatory proceedings or courts.

One example is the International Life Sciences Institute (ILSI), a global nonprofit with a stated mission of providing transparent scientific research in pursuit of a “healthier world.” ILSI—which was founded by a Coca-Cola executive—has cast doubt on, among other things, US guidelines on sugar and the association between sugar and obesity. In 2019, a qualitative analysis of ILSI documents concluded that ILSI is a front group for the food and soft drink industry, working to influence public health and food policies worldwide.²⁴

In addition to front groups, there are all-corporate-purpose think tanks devoted to “free enterprise” and “free markets” and “deregulation.” Dozens of them work on behalf of just about every significant industry in this country. Purdue Pharma and the other manufacturers of opioids used these to great advantage, enabling them to promote the lie that their products were not addictive.²⁵

The idea is to portray front groups and think tanks as serious, independent purveyors of scientific research. And some *do* produce legitimate science for certain projects, while at the same time producing highly questionable science that their sponsoring organizations rely on to promote their unhealthy products.

We all value freedom, in particular the freedom to live the lives we choose—but this is not possible unless we are secure from being harmed by others. In our modern world, individuals cannot bargain with the factory owner polluting our groundwater or the manufacturer contaminating our food.²⁶ We generally have little or no knowledge of the effects of a given exposure—and we may not even know that such exposures are occurring. It is our elected representatives and officials who must enact and enforce laws that protect us from individual and collective harm—from violence and from robbery, but also from dangers posed by tainted food, polluted air and water, unsafe drugs, and dangerous workplace exposures.

Science underpins all of these public health and environmental regulations. The basic principle of the regulatory system holds that decisions must be made on the basis of the best evidence available at the time. Mercenary science obscures that best evi-

dence. In doing so, it doesn't just game our system; it prevents our government from accomplishing one of the reasons for its very existence: to enable some individuals (especially the owners of corporations) to profit by producing something or performing a task that does not impinge on the freedom and well-being of other individuals. We want stronger regulation not because we don't care about freedom, but because we cannot be free without the state's protec-



We need to know that our air is safe to breathe, that our food is safe to eat, and that we can return home from work no less healthy than when we walked out the door.

tion from harm. We need to know that our air is safe to breathe, that our food is safe to eat, and that we can return home from work at the end of our shifts no less healthy than when we walked out the door in the morning. That is both the imperative and, alas, the challenge. □

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Rethinking How to Promote Reading Comprehension

BY HUGH W. CATTS



It is February 2015, and I am at a national conference listening to a panel present the results of their research on improving reading comprehension. Several members of the panel, like myself and a few others in the room, are funded by the Institute of Education Sciences as part of the Reading for Understanding Initiative. This \$120 million program supported six interconnected research teams in their efforts to improve reading achievement in the United States.¹ Educators and policymakers had for some time been concerned about the performance of American children on tests of reading achievement. Over the last 20 years, only about a third of students have scored at the proficient level on the reading subtest of the National Assessment of Educational Progress (NAEP).² This assessment is administered biennially to a representative sample of fourth- and eighth-grade students (and every four years to 12th-graders) from across the nation. Somewhat better, though still troubling, levels of performance have also been reported on state-based reading tests, administered annually starting in third grade. The Reading for Understanding Initiative was intended to jump-start instruction in reading comprehension and significantly improve reading achievement on state and national assessments. In fact, it was described by program officials as the “moonshot” for reading comprehension.

Unfortunately, the preliminary results that the panel presented fell short of these expectations. The reported studies found that students receiving a variety of comprehension interventions made gains, compared with control groups, on assessments closely tied to the interventions—but they showed limited or no significant gains on standardized measures of reading comprehension. Needless to say, conference attendees were surprised and discouraged by these results.

Sitting in the back of the room, I clearly remember not being particularly alarmed by what the panel reported. As part of my work on the Reading for Understanding Initiative and earlier related projects, I had spent many hours thinking, studying, and talking with teachers and colleagues about reading comprehension. Through these efforts, I had come to recognize that the field’s general approach to reading comprehension was shortsighted. We were treating reading comprehension as if it were a single construct that could be measured with one or more general reading tests and improved with a short-term intervention. At a deeper conceptual level, most researchers (including those funded by the Reading for Understanding Initiative) recognized that reading comprehension

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was multidimensional, but it had been common practice in education and research for some time to study, assess, and provide instruction as if comprehension were a skill, rather like swimming. If we teach someone to swim, they can soon transfer that skill to any body of water, whether it be a pool, lake, or ocean. But reading comprehension is not a skill someone learns and can then apply in different reading contexts. It is one of the most complex activities that we engage in on a regular basis, and our ability to comprehend is dependent upon a wide range of knowledge and skills.

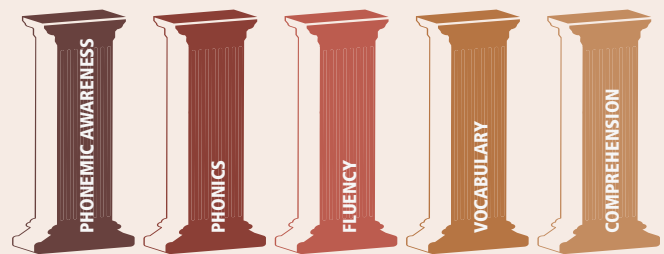
The Comprehension as Skill Myth

How have we come to think of comprehension as a skill? I believe a major reason this has occurred is because we have talked and

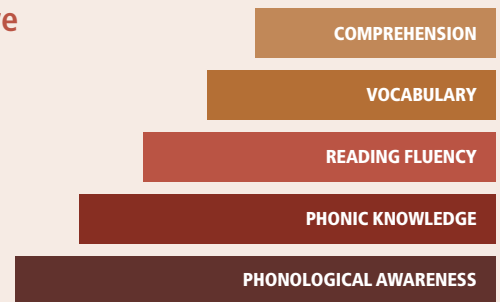
written about comprehension in the context of related skill-like abilities. Discussions about reading often include the topics of phonics, fluency, and related skills, such as phonemic awareness, together with comprehension. As an example, take the work of the National Reading Panel.³ This panel of reading experts was convened by Congress to assess the effectiveness of different approaches to teaching reading. They examined a wide range of instructional approaches related to comprehension, but in overviews of their work, comprehension has been reduced to one of the “Big Five,” along with phonemic awareness, phonics, fluency, and vocabulary.

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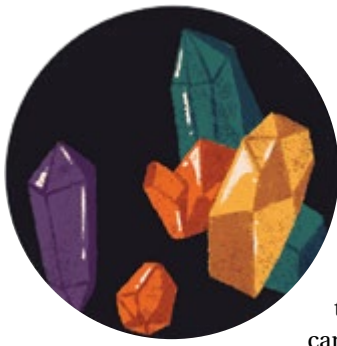
The Five Pillars of Reading Instruction



The Big Five



Common depictions of reading components that give a false impression about comprehension.



As such, it is depicted alongside these skills as one of the “pillars” of reading. In another common graphic, the word *comprehension* is displayed within a box similar in design (actually smaller) to boxes for other skill-like components of reading. Whereas such a consideration and depiction are thought to form a useful heuristic, it can give the false impression that comprehension is comparable to these skills in terms of its complexity and the way it is best taught and measured.

Furthermore, widely used approaches to teaching reading comprehension reinforce this view.⁴ Comprehension has typically been taught through the use of strategies such as “find the main idea,” “make a prediction,” or “monitor your comprehension.” These strategies are taught and practiced in order to gain automaticity, much like what is done with other skill-like behaviors. This, in turn, can lead us to believe that comprehension can be thought of in a similar manner to these other skills.

A More Accurate and Complex Model

Despite this common view about comprehension, several lines of enquiry have recognized the true complexity of reading comprehension for some time. Nearly 20 years ago, this complexity was captured by the RAND Reading Study Group.⁵ This federally funded group was charged with developing a research agenda to address pressing issues in literacy. As part of their 2002 report, they conceptualized reading comprehension as a combination of factors within three different categories: the reader, the text, and the activity of reading.

The *reader* brings a set of cognitive abilities (such as attention, memory, and reasoning), language knowledge and skills, motivations and interests, and background knowledge to the task of reading. Readers vary considerably in these factors, and this variability impacts their comprehension. Considerable research attention has been focused on reader variables, and their impact on comprehension is well documented.

The *text* includes such elements as genre, topic, and complexity. Students encounter texts with different genres—such as narrative, descriptive, expository, or persuasive—and these texts vary in their subject matter and level of complexity. Although not emphasized in the RAND report from 2002, texts also now vary in their form. They may be in a paper or digital form, and the latter can be displayed on a variety of devices, such as a phone, tablet, or computer. Each of these forms imposes its own set of constraints and challenges on comprehension. The notion of multiple texts can also be added to this category to account for the fact that skilled readers often rely on more than one text for comprehension.

The *activity* refers to the task or purpose of reading. It is often argued that the purpose of reading is comprehension. But we actually seek to comprehend for a specific reason, be it to prepare for a test, evaluate the strengths of an argument, learn the rules of a game, or enjoy a magazine article or book. Each purpose brings unique knowledge and skills that must be acquired to be successful.

Importantly, the RAND Reading Study Group viewed these various elements interacting within a sociocultural context that involves factors such as where the reading occurs (e.g., school or home), how much support there is (e.g., individual, teacher- or caregiver-led, or group activity), and what cultural value is placed on reading by students’ families, peers, racial and ethnic groups, and other groups that are central to the students’ identities.

Taken together, it is easy to see how any one individual may have multiple levels of comprehension ability depending upon what they are reading and why they are reading it. As a result, *comprehension cannot be reduced to a single notion because it is not a single ability.*

One individual may have multiple levels of comprehension ability depending upon what they are reading and why they are reading it.

The Role of Knowledge

Chief among the factors influencing reading comprehension is background knowledge. Research clearly shows that how much readers understand about the text’s topic before they read it is a major factor in how much they understand while and after they read it.⁶ Unfortunately, much of the efforts directed toward improving reading comprehension have neglected building background knowledge. (As discussed later, there are widely used strategies for “activating” background knowledge, but they do not necessarily develop new knowledge.) It was this neglect that first alerted me to the problems with the way we were thinking about reading comprehension.

In my graduate training, many years ago, I was introduced to the role of knowledge in reading comprehension. At that time, schema theory was a popular topic in research on human cognition and learning. A schema is an organized unit of knowledge that forms the foundation for many activities involving human thought. Richard Anderson, a professor of educational psychology, brought the notion of a schema to education and argued for its critical role in reading comprehension as well as learning in general.⁷ He was among the first to convey to me the importance of teaching knowledge to improve comprehension.

In my psychology classes, I was introduced to a study that continues to be one of my favorites. The following passage, which was designed to be ambiguous, was read aloud to college students, and they were asked to recall as much as they could.

The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to

go somewhere else due to lack of facilities that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one never can tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.⁸

Students given the topic of the passage beforehand quickly made sense of what they heard and recalled many details. (Those students were told, “The paragraph you will hear will be about washing clothes.”) But those who heard the same passage without the topic were confused and recalled little. Of particular interest, a third group of students was given the topic after they heard the passage, but they too were confused and recalled little. Of course, it was not simply the topic but rather the knowledge associated with it that allowed the students to make sense of what they had heard—but only if this knowledge was available from the start.

It was studies like this, including similar ones involving reading rather than listening, that early on clearly demonstrated for me the importance of knowledge for comprehension. But somewhere along the line, educators and researchers—myself included—got distracted and failed to pay attention to its importance. It is not exactly clear how this happened. Perhaps it was a shift in focus to bottom-up models of reading that argued that meaning was contained within the text and that the reader’s job was to extract it. Or maybe it was just that knowledge took too much time to teach, and it made more sense to focus on skills that could be taught quickly and applied across topics. Also, considering comprehension alongside skill-like aspects of reading probably distracted us from the role of knowledge.

But whatever the reason, knowledge has come back to the forefront in discussions of reading comprehension. Proponents such as E. D. Hirsch Jr., Daniel T. Willingham, and Natalie Wexler have written extensively about the role of knowledge in compre-

hension.* Their work and that of others⁹ has begun to have an influence on research in reading comprehension, but change has been slow. Some of the projects in the Reading for Understanding Initiative did have knowledge as a central component, but the other projects paid only limited attention to knowledge in instruction and/or assessment. Limited attention also plagued other large-scale projects, such as those within the Striving Readers program. This program funded by the US Department of Education involved a set of 17 studies designed to improve reading comprehension in middle and high school students.¹⁰ While materials did address

different topics, there was no direct effort to build knowledge as part of the intervention or assessment. Again, it is not surprising that these studies only demonstrated small effects at best on improving reading comprehension.

What Knowledge Does for Comprehension

Why is knowledge so critical for comprehension? To begin with, it provides a framework for organizing incoming information and guides us as we read through a text. We better understand what the topic is and have expectations about where a passage may be going. By doing so, knowledge keeps us on track and prevents us from going down “blind alleys” in our understanding. This framework also gives us a place to anchor new information in memory and associate it with past knowledge. We use these building blocks of the new and the old to construct an initial understanding of what we are reading and then continuously revise and add to it as we move through a text. It is this integration of the new information in the text with what we already know that brings meaning to what we read.

Background knowledge also allows us to make inferences and fill in information that is not explicitly provided. Authors rarely tell us all we need to know in order to understand a text, so we need to fill in some of the details with our back-

ground knowledge. Knowledge also enables us to more easily recognize which of the multiple meanings of a word is appropriate for the context. For example, when reading a passage about baseball, knowing that the word *pitcher* refers to a person rather than an object could be critical for comprehension.

Knowledge is also essential for thinking. But in certain contexts these days, it is seen as secondary to thinking. Critical thinking has become the rage in education. All too often, teach-



Chief among the factors influencing reading comprehension is background knowledge.

*For articles by Hirsch, Willingham, and Wexler on the importance of building knowledge, see the “Reading” section of *American Educator’s* subject index: aet.org/ae/subject-index.

ers are urged to engage students in thinking deeply and critically about what they read as if these skills were independent of the topic; meanwhile, background knowledge is downplayed as if the specific information about a topic could be looked up on the internet when necessary.¹¹ But it is the specific information that gives students something to think critically about—and our minds are surprisingly limited in how much new information they can take in at one time. Knowledge must accumulate over time to ensure a level of depth that allows for a critical analysis of the subject matter. We can't think logically about different approaches to government without knowing a lot about different forms of government. So, in this sense, knowledge is the most critical component of critical thinking.

Knowledge also allows us to make the most use of our working memory, where much of thinking takes place. There are limitations on how much information we can hold and think about simultaneously in working memory, and this amount is heavily influenced by knowledge. Knowledge coming from long-term memory places a much smaller burden on working memory than new knowledge coming from a text (or a speaker); it also leaves us with more capacity in working memory to think about things in novel ways. As a simple example, it is easier to remember the letter sequences USA, FBI, and NBC than PDQ, RJB, and FVO. When reading, the more information related to the topic we already have stored in long-term memory, the more deeply we can think about that topic—even as we read a passage that offers new information.

Finally, the relationship between knowledge and reading comprehension is reciprocal in nature. Not only does knowledge improve comprehension, but comprehension allows the reader to build new knowledge. Creating a coherent understanding of what one reads modifies the background knowledge that is available for subsequent reading comprehension either later in the same text or in future reading of related texts.¹²

Implications for Instruction

It should be evident from my comments that improving reading comprehension is a complex process that requires multiple levels of instruction and practice. Clearly, building background knowledge that is both deep and broad is needed to lay the foundation for comprehension and for further knowledge acquisition. However, students also need high-quality reading

instruction involving decoding, fluency, vocabulary, and comprehension strategies in order to best use their knowledge in different reading contexts and for different purposes.

For many years, the primary way knowledge has been addressed in the context of reading has been through activating background knowledge using strategies like prereading discussions, concept maps, and anticipation guides. These strategies can be effective—but they only work when the appropriate knowledge is available. Often, children will not have the requisite knowledge, or their knowledge will be impoverished or inaccurate. If inaccurate, this activation can actually be detrimental to comprehension.

Whereas knowledge activation has been widely viewed as a component of reading instruction, building knowledge often has not. In fact, instruction devoted to content knowledge has actually been replaced by other aspects of reading instruction. In most elementary schools, social studies and science instruction has been supplanted by

English language arts (ELA) instruction. Surveys have shown that, on average, children in grades 1–4 receive only 2.3 hours of science instruction per week, whereas four times that amount is spent on ELA instruction teaching word-reading skills, comprehension strategies, and vocabulary.¹³ The thinking has been that if we want children to improve their reading comprehension, we have to work on reading skills to achieve fluency before we can use reading to build knowledge. However, this false dichotomy between *learning to read* and *reading to learn* has not led to better reading achievement.

Recently, educators have begun to rethink reading instruction and consider how to better integrate knowledge acquisition with literacy in ELA instruction.¹⁴ In these more integrated approaches, students build knowledge at the same time they are learning reading-related skills. This involves a concentrated effort to build rich and connected ideas about social studies, science, and other subjects during ELA lessons. Such instruction does not necessarily replace the science and social studies instruction that may be taking place at other times but rather supplements it. As with other content instruction, reading materials in an integrated ELA program are selected to build knowledge. Instead of reading, for example, about volcanoes one day and Rosa Parks the next, which has often been the case in ELA instruction, reading materials are arranged by topic in a logical and sequential manner and form an integrated, content-rich curriculum. In this way, knowledge is acquired and accumulated over time.

Such content-rich, connected instruction can be especially engaging and can draw children's interests to literacy and learn-



Our minds are surprisingly limited in how much new information they can take in at one time.

ing. Student engagement and learning can be further fostered by culturally responsive instruction. One example is a program called Readiness through Integrative Science and Engineering.¹⁵ This program takes a home-to-school approach to connect new knowledge with culturally relevant knowledge concerning the people, places, and objects that students interact with on a daily basis. By understanding, appreciating, and connecting with this knowledge, learning can be especially enhanced for all children.

In an integrated literacy and knowledge-building curriculum, there should be a strong focus on teaching fundamental reading skills. Depending on the grade and specific skills taught, instruction in decoding, spelling, and fluency could comprise its own unit or be blended with discussion and activities designed to acquire and build content-area knowledge. Vocabulary, an important focus of ELA instruction, can be taught especially well within a content-rich, integrated curriculum. Novel words related to the content are excellent targets for instruction. These words are often repeated multiple times in a text, and their meanings are well supported by the context in which they occur. In addition, once learned, they become part of the knowledge base of the topic. General-purpose academic words, or what are sometimes referred to as Tier 2 words, also are learned more easily in a rich context. When these words are supported by content knowledge, the reader can use this knowledge to more easily infer their meaning. Also, a rich context can prove particularly helpful in learning words with multiple meanings, such as “bright” or “palm.”¹⁶

Content-rich materials are also excellent contexts in which to learn more about academic language. Written language is characterized by more complex grammar than spoken language, and students can benefit from explicit instruction in how this grammar works. Specifically, science texts tend to privilege nouns for compacting information, developing logical reasoning, and achieving precision.¹⁷ For example, consider this text: “Asthma is a disorder in which the respiratory passages narrow significantly as a result of an allergen. This narrowing...” Here the author creates an abstract noun (i.e., “this narrowing”) to represent the entire previous clause. Recognizing the referent of this abstract noun is critical to comprehension and, in cases like this, could benefit from explicit instruction. In other academic texts, students will be confronted with complex and elaborated noun phrases, rather than reduced ones, as well as challenging noun, adverbial, and adjectival clauses. For example, social studies texts use “noun clauses (e.g., ‘Jefferson’s next argument was that King George III had violated the colonists’ rights by passing unfair laws and interfering with colonial governments’), adverbial clauses (e.g., ‘Even before Washington reached Boston, the Patriots took action’), and adjectival clauses (e.g., ‘He was influenced by the Enlightenment idea of the social contract, which states that governments and rulers must protect the rights

of citizens’) to pack a large amount of information.”¹⁸ Given this complexity, explicit instruction in how to unpack academic grammar could prove helpful to students in understanding informational texts.

Integrated approaches also can incorporate many of the same comprehension strategies employed in traditional ELA instruction. Some of these strategies, like inferencing and paraphrasing, are rather general and can be explicitly taught and used across various contexts. However, within an integrated approach, some strategies are best selected and taught based on their relevance to what is being read and for what purpose. The nature of texts and purposes for reading vary across subject matters, and thus, the strategies that may be most advantageous will vary as well.

Some of these strategies will be the common ones (e.g., mental imagery) identified by the National Reading Panel. Others will be more text- and task-specific metacognitive approaches to assist comprehension. For example, during a social studies lesson, students may be presented with an explanation or argument and asked to evaluate its validity. In such a case, students would benefit from explicit instruction and practice on how to identify a claim and judge the relevance, sufficiency, and accuracy of the evidence provided. Alternatively, science texts often provide

a description of some object, animal, or process, and students are often tested on what they have learned from their reading. For such a task, students may benefit from being taught how to use a graphic organizer to summarize and categorize the information within different organizational structures. Students will also benefit from recognizing that a science text (from a trustworthy source) is an authoritative account and is different from texts in which the

author’s perspective is central, such as a poem or a historical figure’s diary entry.

This more nuanced approach to strategies becomes ever more important as students move through the grades and the comprehension skills needed are increasingly determined by the characteristics of the text and the

activities carried out within the different disciplines. Nevertheless, knowledge of how disciplinary texts work, or what is called disciplinary literacy, can and should be part of instruction in the elementary grades.¹⁹

There are now quite a few integrated, content-rich curricula being used across the country. Some of these programs are commercially available through curriculum publishers, such as Core Knowledge Language Arts and Wit & Wisdom, whereas others

Knowledge must accumulate over time to ensure a level of depth that allows for a critical analysis of the subject matter.



have been developed by researchers, such as Model of Reading Engagement.²⁰ Some of these programs have been developed specifically to be used as part of ELA instruction. Others are truly integrated across the curriculum and operate instead of or in addition to ELA materials. There is also quite a bit of variability in the scope of literacy instruction within these programs. Nevertheless, a recent meta-analysis showed that when compared with traditional programs in which literacy and content instruction were provided separately, integrated, content-rich programs resulted in students scoring significantly better on vocabulary and comprehension (including on standardized measures of comprehension). Not surprisingly, significant gains were also made in the content taught.²¹

Implications for Assessment

The multidimensional nature of reading comprehension presents a significant challenge for assessment. Because of the numerous factors in play, a reader's comprehension ability is more fluid than often thought. In other words, any one individual will have different levels of ability depending on what is read and for what purpose.

Perhaps the best demonstration of this variability and its impact on assessment comes from a study that included scores from 995 children who were administered four different standardized measures of reading comprehension.²² The researchers found that the median correlation between the different tests was only .54, which was surprisingly low given that the tests purported to measure the same thing. In another analysis of the data, they identified children scoring in the lowest 10th percentile on each of the measures and compared the overlap of these groups across measures. Their results showed that, on average, only 43 percent of the children identified by one test as poor readers were also identified as poor readers on another test. In other words, *the odds of any two tests diagnosing the same student as having a comprehension deficit were less than half*. Further analyses showed that it was not just a problem of consistency at the lower end of the scale; there was just as much inconsistency in identifying children performing in the highest 10th percentile.

The inconsistency in the results of the different measures of reading comprehension was likely due in part to the poor reliability of these measures, something that is not uncommon for diagnostic measures of reading comprehension. On the other

hand, the measures also differed in their formats, so that could have contributed to the variability. One measure employed a cloze task in which children read passages and filled in missing words. In the others, children read either passages or single sentences and then answered open-ended or multiple-choice questions. These formats are known to place different demands on reading-related processes, such as word reading, language ability, and working memory.²³ Thus, children with different strengths and weaknesses in these processes would be expected to perform differently on the measures.

The content of the passages/sentences may also have added to the variability of the measures. That is, children were likely to have varied in their knowledge about the topics covered, and

that could have influenced their performance. Such variability may be present not only across tests but also across passages within a test. For example, in the Reading for Understanding project that my colleagues and I carried out, students read four different passages from an informal reading inventory and answered open-ended questions. We observed considerable variability within students from one passage to another. It was not uncommon for a student to get nearly all the questions correct on one passage and most wrong on another. Whereas there may be several reasons for this variability, differences in background knowledge is a likely contributor.

Because of the variability due to passages, state- and national-level tests of reading use numerous passages that cover multiple topics. But, of course, this introduces the problem of these tests favoring students who have more knowledge about a broad range of topics than those with less knowledge. This has led E. D. Hirsch Jr. to argue that reading tests are actually knowledge tests in disguise.²⁴

The fact that state and national reading tests are knowledge heavy introduces a further problem: performance on these tests will likely be more difficult to change in the short term, since knowledge acquisition is incremental in nature. Indeed, as I stated at the outset, American children's performance on NAEP has remained virtually unchanged for some time. This has been in spite of significant federal, state, and local efforts. For example, in North Carolina, the percentage of students failing to reach proficiency on state reading tests has remained largely unchanged, hovering above 50 percent, since 2013–14, when the state passed its K–3 Read to Achieve literacy act.²⁵

Maybe the problem is not only the instructional practices teachers have been encouraged to use but also the way we are assessing comprehension. An alternative approach would be to teach children using an integrated literacy and content-rich cur-

Maybe the problem is not only the practices teachers have been encouraged to use but also the way we assess comprehension.

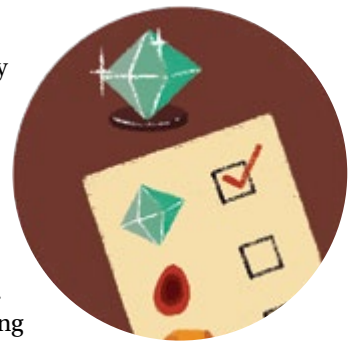


riculum and to test their ability to read and comprehend passages covered in that curriculum. In other words, offer a better match between instruction and assessment. Don't just test the skills and strategies that have been taught; test the specific content-area topics that have been taught. Such an approach would be fairer and more equitable for all involved. Teachers would have a clear idea of what content within which to imbed their literacy instruction. Students would have the opportunity to learn from content-rich curricula and be assessed based on what they learned in school (instead of what they may or may not have learned at home, over the summer, etc.). Also, because instruction would be better matched with assessment, there would be a greater opportunity for schools and districts to evaluate the progress they are making.

One approach that has attempted to better match instruction with assessment is being carried out within the guidelines of the Every Student Succeeds Act assessment pilot program.²⁶ This program encourages local involvement in the development of the next generation of assessments. It allows states, with approval by the US Department of Education, to pilot new and innovative assessments in lieu of current state exams. Initially, this takes place in a small number of districts before moving on to statewide implementation. As of October 2021, five states have received approval to develop these assessments. Most notable, Louisiana has begun a multiyear process to offer a humanities assessment as an alternative to its English language arts and social studies assessments.²⁷ The new humanities assessment draws from texts and topics that are included in the state's recommended curriculum.²⁸ Thus, the content of the test is likely to be well matched with the instruction students receive.

A very limited pilot of this new assessment, LEAP 2025 Humanities, began in the 2018–19 school year, and then implementation was interrupted by the pandemic,²⁹ so it will likely be several more years before researchers can evaluate the impact of this new approach. Of course, designing an assessment that is in keeping with current research on literacy development is just the first step. The extent to which the assessment will help enhance instructional practices depends on many related components, including meaningful professional development on how to use the results to inform teaching; time (appropriately allocated and compensated) for teachers to learn collaboratively as they adjust to the new assessment; genuine opportunities for all teachers to have a voice in providing feedback on the curriculum and assessment; and lower stakes tied to the assessment results such that teachers are not afraid to be innovative. In fact, one of the findings of the Reading for Understanding Initiative was that “a major roadblock to teacher uptake of new practices is the accountability infrastructure of reform movements. The more test scores matter, the less the likelihood that teachers will adopt novel teaching practices.”³⁰

Still, I am especially encouraged by Louisiana's efforts and am hopeful that other states and districts will also consider how to better align what is tested with what is taught. It is these types of programs, combined with integrated literacy and content-rich curricula, that I believe can better address comprehension. These programs move beyond characterizing



comprehension as simply one of the “Big Five” and recognize its complexity and what it will take to help all children understand and learn from what they read. I look forward to attending future conferences where the results of these programs are presented. □

An alternative approach is to test the skills, strategies, and specific content-area topics that have been taught.

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Sharing Their Ideas with the World

Creating Meaningful Writing Experiences for Young Children



By Hope K. Gerde, Tanya S. Wright, and Gary E. Bingham

Writing gives children a way to share their voices and ideas with the world. Even in early childhood, the purpose of writing is to communicate. All young children have messages to share, and writing is one tool they can use to communicate those messages. But even though the adults—from teachers to family members—who are caring for and educating young children value those messages, it is easy to miss early writing attempts because these do not look like conventional writing.¹ For example, when children scribble, they are often writing, and drawing and writing are not always easy to distinguish. If we invite children to tell us about their work

in open-ended ways (“Tell me about what you’ve made...” rather than “Did you draw your puppy?”), they may reveal that they have been writing (“I made my name!” or “It says *happy birthday to mommy*”). Once adults are attuned to children’s early attempts at written communication, there is much they can do to be supportive. While this article offers detailed guidance for preschool and prekindergarten teachers on early writing development, there are also simple steps teachers can share with family members, like inviting children to both write and dictate their messages and helping children use letters to label their drawings. But first, let’s break down what writing is and why it is so important.

There is strong agreement among researchers that writing includes both composition and transcription.² Composition is the creative process in which writers identify the purposes of their messages, generate messages (including ideas and stories), and carefully select words to share them.³ For example, a preschooler might draw a red circle with a diagonal line through it and say, “This sign is so no one knocks down my tower.” Transcription—which includes handwriting and spelling—is the mechanical process that allows writers to represent their messages using established conventions (enabling others to understand them). For young children, handwriting focuses on

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learning how to make the shapes of letters (i.e., not on making perfect letters or writing letters on lines). Spelling refers to skills for matching letters to sounds in order to write words. As young children transition from scribbling to writing letters and words, they invent much of their spelling by writing the sounds they hear in words. Through explicit teaching of sound-spelling correspondences in which reading and writing are practiced together, children slowly learn standard academic spelling across the early childhood and elementary years.⁴

Even for college-educated adults who no longer have to devote much thought to the mechanics of writing, capturing their ideas in text is a complex task. For young children, it is quite challenging to form and remember messages while also figuring out how to put them on paper. Studies demonstrate that executive function skills, including self-regulation, are needed so that children attend to and persist in this complex task.⁵ Writing engages young children across developmental domains and activates motor, cognitive, and socioemotional learning.⁶

Why Is Early Writing So Important?

Young children (ages 3 to 5 years old) learn a lot from early writing opportunities. Early writing development predicts later reading and writing achievement.⁷ Moreover, young children tend to enjoy writing, particularly within the context of meaningful opportunities to express their ideas.⁸ So, what exactly do young children learn when they engage in writing?

Children learn the importance of communicating ideas through written text and images. When children engage in composing, they learn about meaningful purposes for writing and begin to understand the relationship between oral and written language. Consider 3-year-old Jaylen, who is eager to perform music in his classroom's pretend theater and needs an audience. His teacher, Ms. Lopez, encourages Jaylen to make an invitation to his show. "You can write down your message to invite others to your performance," she tells him, providing a purpose for his writing. She asks Jaylen to verbalize what he wants to tell his classmates about his show. Jaylen says, "I play music. Drums. Pretty music. They can listen or play." Ms. Lopez offers encouraging feedback by saying, "That's an important message. It tells others what you will do and what they can do."

Recognizing Jaylen's message is long, Ms. Lopez condenses it, suggesting, "So you want to say, 'Music today, listen or play.'" Jaylen corrects her: "Pretty music." Appreciating Jaylen's attention to word selection, Ms. Lopez revises her suggestion, saying, "Pretty music today, listen or play." Smiling to signal his approval, Jaylen writes some scribbles on the page along with his name and a picture of a drum. He "reads" his message aloud—an indication that he recognizes that his print has meaning—saying, "I play pretty music, you can listen or play." Ms. Lopez reinforces the relationship between verbal and written language by stating, "Jaylen, you wrote the words you said. Now, use your invitation to invite the class to your show."

While Jaylen did not write conventionally (i.e., he did not use letters to spell words), this example illustrates how he used oral language to compose his message, considered word selection, and recognized that print has meaning. In addition, Ms. Lopez provided a purpose for his writing, helped him to revise his message, and reinforced the relationships between oral and written language.

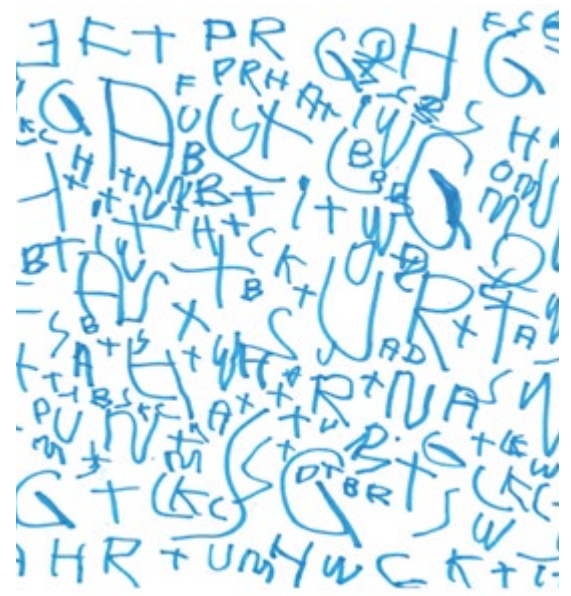
When teachers encourage any form of writing, they show that children's ideas are valued.

Children learn how text works, including foundational concepts like letter-sound relationships. Young children's writing attempts are opportunities to practice and to extend what they know about how written text works. Even before young children can write letters, they might create rows of scribbles when making a grocery list or write a few letter-like shapes to make a sign. These writing attempts provide insights into what children know about writing for different purposes, starting long before they learn about letters and sounds.

Now consider Tamara, a 4-year-old who picks up a marker and draws a big red circle. Tamara says the word *stop* quietly to herself several times, then says "sssssssss" as she slowly writes a backward *S* inside the circle. Working through the rest of the word, she says "sto... p, sto... p, p, p," as she writes a *P*. Tamara then cuts out the shape and brings it over to the trucks she has been racing with friends to use in their play. She says, "OK, you got to make your truck stop right here," as she places her stop sign on the floor.

This brief writing event tells us so much about Tamara's literacy learning. She has noticed that print in the environment (e.g., a





stop sign) has meaning, which is an important print concept for young children. She understands print as being useful and meaningful to others. She understands that we write words with letters, and she is attempting to form letters even if she does not yet understand that letters must face a particular direction. She knows that words in oral language can be broken into individual sounds (i.e., she is developing *phonemic awareness**). Tamara's phonemic awareness is evident when she tries to figure out the sounds in the word *stop*. She can represent the /s/ sound with the letter *S* and the /p/ sound with the letter *P*, demonstrating an understanding that letters represent sounds (i.e., *the alphabetic principle*) and of particular letter-sound relationships. In creating her stop sign, Tamara provides a rich example of how and why opportunities for writing in early childhood are associated with the development of print concepts, phonological awareness, and letter knowledge,⁹ which are all foundational skills¹⁰ for both reading and writing.

Intentional Supports for Early Writing

Recent research indicates that most preschools could offer far more opportunities for children to write for communication.¹¹ One potential topic for professional development is how early childhood educators conceptualize writing. If teachers understand writing as *only* a spelling and handwriting task,¹² they may not recognize opportunities for children to use writing like Jaylen and Tamara did—to share their messages—and to enhance their literacy development while engaging in other activities. In our recent research interviewing a diverse group of preschool teachers, we found that very few educators articulated beliefs or reported practices that centered writing instruction on encouraging children to compose their own messages, share their ideas, or otherwise make meaning.¹³ We also found that very few teachers used writing to support broader literacy learning. For example, even though almost all teachers had writing centers and activities in their classrooms, they tended to focus on name writing and

letter formation; only about a fifth of the teachers allowed children to take writing materials into other spaces so that writing could be part of their play. For us, a big takeaway from the study is that early childhood educators would benefit from opportunities to reconsider the many ways that early writing reinforces fundamental literacy goals (like developing young children's concepts of print) and encourages children to share their thoughts.

Research has found that children in classrooms where early educators support composition and meaning making demonstrate more advanced writing at the end of preschool than children in classrooms where only handwriting and spelling are supported.¹⁴ Clearly, when opportunities for meaningful writing exist, young children learn a lot! Here, we describe several research-based ways for preschool and prekindergarten teachers to intentionally support meaningful early writing opportunities for children.

Provide and draw attention to writing materials and environmental print resources. Young children benefit from classroom environments that are filled with writing materials and environmental print supports (e.g., signs in the classroom that pair text and images).¹⁵ Classrooms that are designed to support young writers have varied and plentiful opportunities for children to see print. But merely having the materials in the room is not enough. Print or writing materials in the environment do not support children's learning if they are not both purposeful and used by children regularly; teachers must explicitly show children how to use these materials and create meaningful opportunities for using them.¹⁶

Teachers can promote children's writing by providing various writing instruments—crayons, pencils, markers, chalk—and surfaces to write on—paper, dry-erase boards, chalkboards. Making plentiful and varied materials available communicates the importance of writing. These materials motivate young children to write and support their motor development as they learn to hold and press a number of different writing utensils.

Writing materials and other print resources should be available in a dedicated writing area that children can frequent during free-choice times, and they should be placed throughout the room in meaningful ways. For example, writing implements like paper, pencils, washable markers, and clipboards can be added to any dramatic play area. That way, students can act out how adults use

*For more on phonemic awareness and effective literacy instruction, see "Teaching Reading Is Rocket Science" in the Summer 2020 issue of *American Educator*: aft.org/ae/summer2020/boats.

writing within various roles (e.g., people working in stores write on order forms and price tags, and forest rangers write on trail maps and wildlife logs). Science and math areas are enhanced by including opportunities for recording data and measurements on graph and chart paper or in journals. Unlined paper in the library may prompt children to write about the books they read or make their own books. To encourage writing and support children’s developing letter-sound knowledge, an alphabet chart with images reflecting the sounds that each letter represents should be prominently displayed at children’s eye level to support their writing.

Teachers must explicitly support young children in using these print resources. For example, a teacher might reference the alphabet chart to help a child write the word *mom* when composing a letter. “Which letter on the chart makes the *mmm* sound like *mmmom*? I see you are pointing to the *M*. On the chart, there is a picture of the moon next to *M*. *Mom* and *moon* both start with the *mmm* sound, and we make that with an *M*.” Other print resources that can be referenced daily are the class schedule, a snack or lunch menu, or a sign-in sheet.

Accept and encourage writing attempts. Children’s early writing attempts, including scribbles or letter-like forms, lay an important foundation for writing letters. When teachers encourage any form of writing, they show that children’s ideas are valued and help children to see themselves as writers, to participate in writing before they have well-developed motor or spelling skills, and to understand the connection between oral language and print.

Teachers play a huge role in young children’s writing by nurturing their efforts. But before teachers can celebrate children’s efforts to communicate through print, they need to intentionally look for and learn to quickly recognize children’s early writing. Children’s writing attempts may look different depending on their home language and their previous exposure to writing at home and school. For bilingual children, writing attempts in both home and school languages should be accepted and encouraged. This includes children’s attempts to write words in their home languages as well as their use of the written symbols of these languages. For example, children who see written Chinese or Arabic in their homes may try to write symbols that look like the orthography of these languages.¹⁷ Learning to recognize everything from the earliest scribbles to attempts to form Cantonese characters is challenging. Fortunately, young children tend to be very receptive to open-ended inquiries about their work. For a scribble that could be a drawing or writing, a teacher could say, “You are creating many different lines. Tell me about these lines.” For children

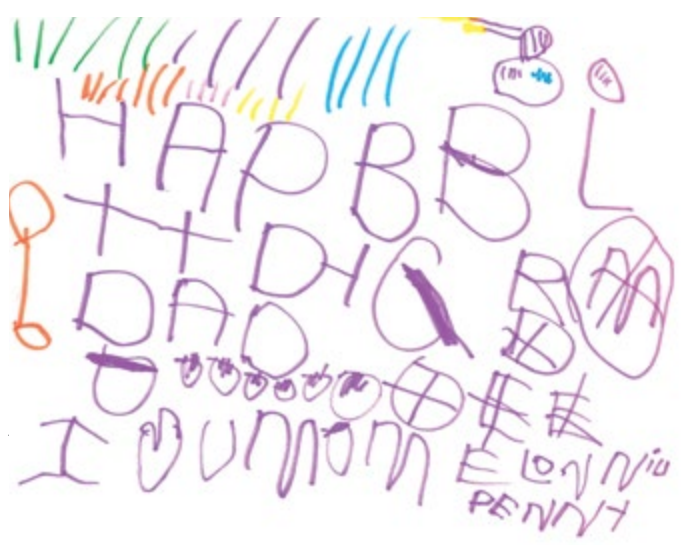
For young children,
purposeful writing-
related interactions occur
when writing becomes
part of play.

with less expressive language, you might ask them to point to or show you what they are making. For a piece that is clearly writing but is not decipherable, a teacher could say, “I see that you are writing. Tell me about your message.”

Because preschool and prekindergarten classrooms tend to include children with a wide range of writing skills and experiences, teachers can create writing opportunities that allow children to participate in varied ways. When choosing a beverage for mealtime, for example, children could have options for responding to the question “Do you want water, juice, or milk?,” such as recording a tally, creating letter-like forms, or writing letters. For dual language learners, providing various scaffolds (and appreciating where children are developmentally in each language) can support bilingual children in communicating ideas in writing. For example, when the class is writing a thank-you note, the teacher can draw attention to the varied ways in which we write *thank you* by saying, “You can write *gracias* if you want to say *thank you* in Spanish.” Explicitly valuing children’s home languages[†] not only supports bilingual children’s learning but also strengthens monolingual children’s orthographic knowledge by highlighting how different languages represent oral language in different ways.

Connect writing to thematic units and children’s play. Early childhood teachers have a unique opportunity to connect writing experiences to curricular units in ways that deepen children’s interest in writing, help children understand the varied purposes for generating and recording ideas, and create opportunities to share content knowledge. For young children, purposeful writing-related interactions occur when writing becomes part of play—thus allowing teachers to support and engage children in writing instruction that is meaningful to their interests and development.¹⁸

Opportunities to write across genres within a thematic unit of play include communicating information to others (informational), telling others how to do something (procedural), or convincing others that something is important (persuasive).¹⁹ If children create a restaurant, for example, they may write a menu to inform diners of their options, write recipes to show how dishes on the menu should be prepared, and write an advertisement explaining why their restaurant uses locally grown ingredients.



[†]For more on celebrating students’ home languages and linguistic strengths, see “Bilingualism and Biliteracy for All” in the Summer 2020 issue of *American Educator*. aft.org/ae/summer2020/lu.



As children learn about a theme or topic, the goal is to show children real ways adults use writing to communicate in their daily lives. For example, during a unit on pets, Mr. Patel sets up an animal hospital play center. The setting allows children to

- record injuries and illnesses on animal health charts,
- label animals and their body parts using word cards with pictures,
- write their names on checkout cards to take care of animals,
- record things that the animals need (e.g., Have they been fed? Have they been groomed? Have they been walked or cuddled?), and
- generate and write (or draw) fliers persuading others to adopt a pet.

Mr. Patel uses the animal hospital to facilitate children's self-directed play and to base whole-group instruction on children's interests. For instance, Mr. Patel watches as Lily explains to Mason that her cat hurt its tail and needs the veterinarian's help. After Mason circles the tail on a cat picture, Mr. Patel helps them write "hrt tal" and asks if they would like to post this writing on the class meeting board for later in the day when the class will discuss and write steps informing others about how to care for animals. Lily and Mason agree, and soon they are getting the other children excited about helping Lily's cat during their group time.

Provide multiple ways for children to participate in interactive writing. Interactive or shared writing, a strategy in which both the teacher and the child participate in "sharing the pen," is an important way to promote early writing.²⁰ During interactive writing, the teacher intentionally capitalizes on what individual children can contribute to engage them in learning about writing and literacy.

It's beneficial to intentionally engage children's oral language and print knowledge skills through interactive writing. To promote oral language, teachers can ask a child to say aloud their message as the teacher records the child's words. To expand the experience, the teacher can ask questions while they write together to encourage the child to add more details. To enhance vocabulary, teachers can offer new or alternative word selections. For example, "Do you

want to write about a *friendly* or a *fierce* monster?" And to solidify the relationship between oral and written language, teachers can prompt children to read their message aloud.

To support knowledge of print concepts, such as sentences are made of words and words are separated by spaces, teachers can prompt children to count the number of words in their message and then draw a line to represent each word. Teachers can then prompt children to identify sounds in the words in their message and figure out which letters represent these sounds. Children can record the letters they know, and the teacher can fill in the rest. As children learn more about letters and sounds, they can do more of the writing with less teacher support. Young children are excited to read back the words they have written.

Observe children's writing to inform instruction. Children's writing tells us a lot about what children want to say, what sparks their interest, and what they know about how print works and about different types of writing. For example, a child who writes "Mom" on the top of the page, draws a heart in the middle, and signs their name at the bottom of the page knows something about writing a letter. A child who scribbles on a notepad as they take an order from a customer in the classroom restaurant recognizes that language can be recorded and that print has meaning. A child who writes a string of letters from left to right and continues on the line below demonstrates understanding of the directionality and linearity of print. A child who writes "Hpe Bd" on a Happy Birthday card for a classmate demonstrates knowledge of some letter-sound relationships.

Children vary widely in their writing development from ages 3 to 5. Therefore, teachers can examine children's writing artifacts to identify what they know and do not yet know about writing and print. This knowledge can be used to individualize writing support.²¹ That is, for children who draw and scribble, teachers can direct their attention to written text in books and on signs to encourage the use of print in addition to their drawings. For children writing letter strings (i.e., letters without associations to sounds), teachers can teach letter-sound relationships and prompt children to identify and record initial sounds in words. Children who write letters to represent the first sounds in words can be encouraged to write letters reflecting more of the sounds they hear.

When young children are recognized as writers, their ideas are acknowledged as valuable and their writing attempts provide opportunities to support their developing language and literacy skills. Children's writing also lets teachers observe children's developing understandings about literacy in order to teach what children need to learn next.

Imagine a preschool classroom where children have regular opportunities to engage in early writing with support from adults who provide writing materials, draw children's attention to print and its purposes, express genuine interest in and ask questions about their ideas as they write, help children to segment the sounds in words they want to write, and show children how to form letters that represent those sounds. For children, the focus is on communicating. For teachers, these writing experiences also provide meaningful opportunities to strengthen children's critical early literacy skills and to ensure that all children feel that their ideas are worthy of sharing. □

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All Children Thriving in All Settings



In the Fall 2021 issue of American Educator, Pamela Cantor's article, "All Children Thriving: A New Purpose for Education," offered a vision, grounded in decades of research and experience, for maximizing the potential of all children in all settings (see aft.org/ae/fall2021/cantor). Much of that article focused on schools, and further details are available in Design Principles for Schools (turnaroundusa.org/design-

requires a shared understanding of where and when learning happens, acknowledging all the settings where young people spend their time, not just classrooms.

Recommendation 2: Prioritize strategic partnerships. Valuing and prioritizing partnerships between schools and community partners requires an intentional outreach and engagement strategy, with resources dedicated to nurturing and maintaining partnerships. Community schools are one approach to aligned partnerships where coordinators facilitate and provide leadership for the collaborative process and development of a continuum of services for children, families, and community members within a school neighborhood.

Recommendation 3: Prioritize and improve coordination throughout the learning ecosystem. National youth-serving organizations with affiliate models, afterschool and summer learning intermediaries, and local children's cabinets play a critical role in taking science-aligned approaches to scale in communities. Working through their networks, these organizations support professional development, program quality assessment, and effective use of data. Further, local coordination of community programs paves the way for school-community partnerships. However, this kind of coordination will not happen without dedicated staff time across all the settings and sectors that comprise the learning and development ecosystem.

Recommendation 4: Strengthen and expand cross-setting adult capacity building. One way to ensure that youth experiences are consistent across settings is to give adults across settings access to common professional development resources and trainings. Schools and districts should invite community partners to lead trainings and initiatives designed to improve youth outcomes through high-quality enrichment opportunities, including STEM, project-based learning activities, and summer enrichment programming, as well as address issues such as trauma, chronic absenteeism, diversity, and inclusion.

Recommendation 5: Increase and stabilize funding for community programs. Community partners can bring unique assets and often serve as the bridge between schools and families. Stable funding would allow community programs to deepen their practice, improve quality, and serve more students. Educators and community practitioners need to band together to help funders and policymakers understand why investing in community learning opportunities will contribute to a healthy, productive workforce.

Taking an ecosystem approach that embraces the notion that all settings matter will lay the groundwork for creating the optimal and equitable conditions for healthy learning, development, and thriving that each and every learner should experience.

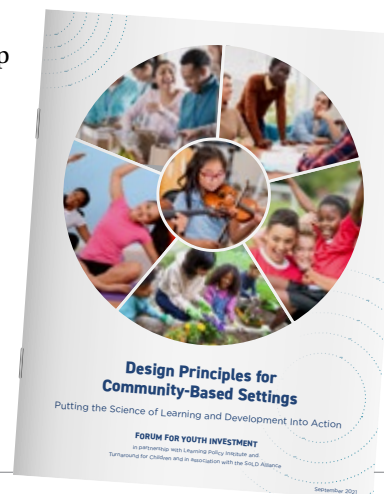
principles). Here, we provide an excerpt of the companion report, Design Principles for Community-Based Settings (bit.ly/CommunityDesignPrinciples), which aims to foster deep collaborations across learning environments—in and out of school buildings.

—EDITORS

Developmental and learning science tell an optimistic story about what all young people are capable of. There is burgeoning scientific knowledge about the biologic systems that govern human life, including the systems of the human brain. Researchers who are studying the brain's structure, wiring, and metabolism are documenting the deep extent to which brain growth and life experiences are interdependent and malleable. Because researchers know so much more about the brain and development than they did when the 20th-century US education system was designed, we can now use this knowledge to not only redesign that system but affirm a healthy learning and development ecosystem that fully acknowledges the role of families and communities as instrumental places for engaged learning.

As learning is about meaning making—connecting new information and experiences to those that have come before—an awareness of what young people are experiencing in the broader ecosystem is essential. As schools across the country tackle this challenge, they are acknowledging the value of rethinking their role within the ecosystem. The power to transform learning settings and achieve equitable conditions for learning *at scale* rests on the ability of communities to embrace and deliver integrated, cross-setting approaches to science-aligned transformation. Therefore, *Design Principles for Community-Based Settings* offers recommendations for promoting a connected and aligned learning ecosystem.

Recommendation 1: Recognize community programs as an essential part of the learning ecosystem. Schools and community partners can co-create a vision of student success that reflects the values and culture of the community's students and their families and is fully supported by science-aligned approaches. The sheer diversity of community programs means that they do not always present a visible, coordinated force in their communities, yet we know that for many young people, community programs can allow them to thrive. Vision setting



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