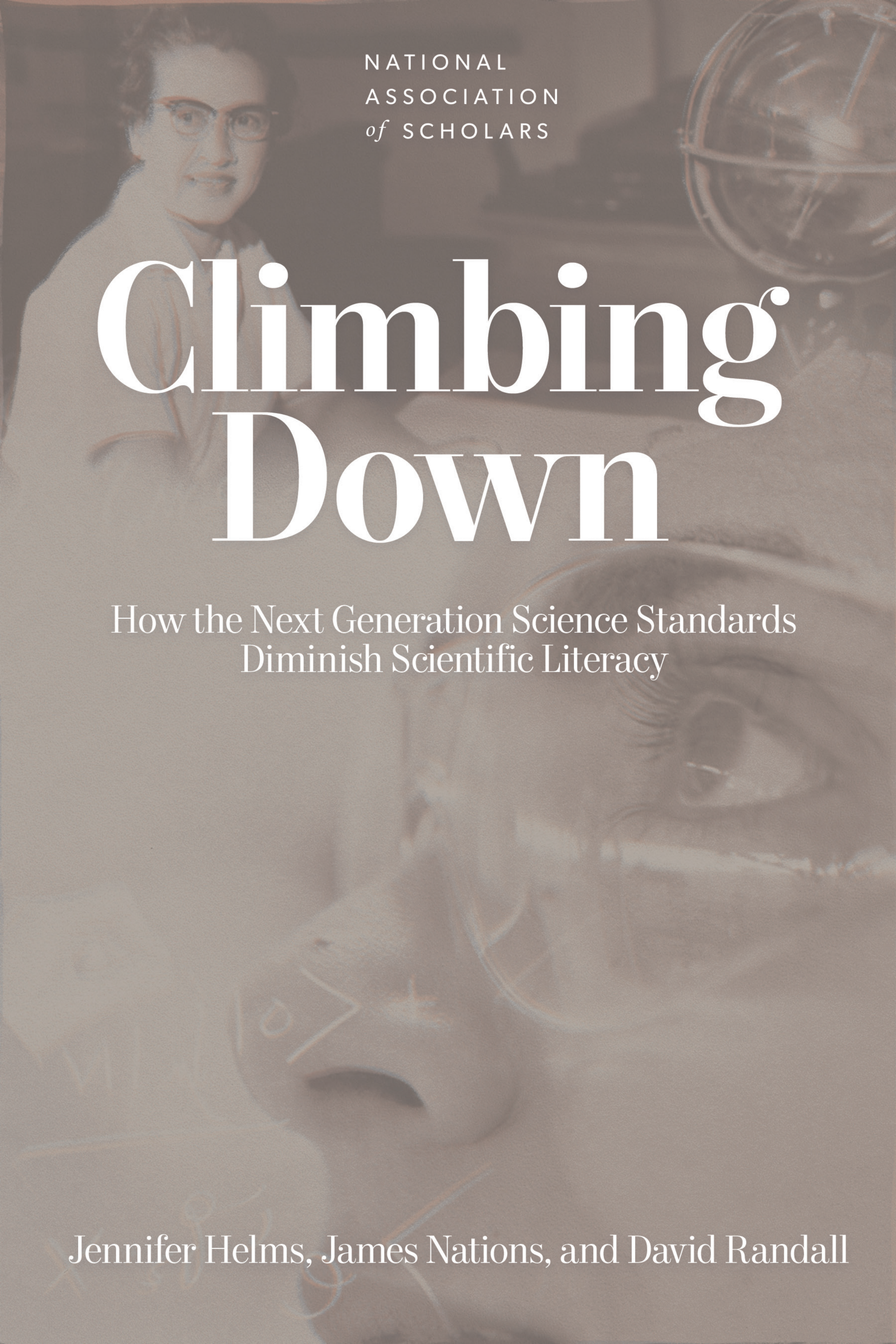

NATIONAL
ASSOCIATION
of SCHOLARS

Climbing Down

How the Next Generation Science Standards Diminish Scientific Literacy

Jennifer Helms, James Nations, and David Randall

Climbing Down

How the Next Generation Science Standards Diminish Scientific Literacy

A report by the

NATIONAL ASSOCIATION *of* SCHOLARS

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We publish a quarterly journal, *Academic Questions*, which examines the intellectual controversies and the institutional challenges of contemporary higher education.

We publish studies of current higher education policy and practice with the aim of drawing attention to weaknesses and stimulating improvements.

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Cont

ents

Preface and Acknowledgments

Peter W. Wood
President
National Association of Scholars

American science is on the brink of a terrible decline. At our postwar apex, American scientists and engineers produced such triumphs as the polio vaccine, the laser, the moon rocket, and the personal computer. A host of Nobel Prizes bore witness to the theoretical advances pioneered by American scientists.

By many estimates, American science has suffered though several decades of relative stagnation, in which we have seen modest gains rather than significant strides. The scientific establishment, however, has tended to exaggerate these incremental advances. It boasts that contemporary science continues to score breakthrough after breakthrough. At stake is the need to convince the public that the many billions of dollars of taxpayer money spent on scientific research each year are wisely invested.

The National Association of Scholars (NAS) is a vigorously pro-science organization. We recognize that systematic and disciplined inquiry into nature has shaped the modern world, mostly for the better. The aspiration to extend man's understanding of biology, chemistry, physics, and the other natural sciences is both worthy and fruitful. And because we uphold that view, we are alarmed when we see forces at work within the institutions of science that check or compromise legitimate inquiry.

Such forces are not necessarily new. The appeal of irrational explanations of natural phenomena is age-old, and the readiness of people to credit ideas that are flatly contradicted by the available evidence has an equally long pedigree. Science has always been a hard-won intellectual gain in competition with superstition, dogma, and ignorance. The worst situations arise, however, when superstition, dogma, and ignorance dress themselves up as science and attempt to usurp the authority of science to advance their own ends.

Some scientific professional organizations now deform themselves to conform to an ever-lengthening series of political agendas, including climate change, anti-conservatism, and "anti-racism." Scientific journals now retroactively "cancel"—remove from the public record—scholarship that contravenes political dogma.[1] Science departments and granting agencies demand "diversity statements" from science professors—statements which are demands for conformity to progressive political belief. The practice of American science is rapidly becoming Lysenkoist—party line first, scientific inquiry a distant second.

American K-12 science education compounds this decline. Our schools are failing to educate students to be prepared for undergraduate science education—while also teaching them that political conformity is the essence of science. We cannot fix American science without fixing our K-12 science education.

The National Association of Scholars expands its remit with this report on the Next Generation Science Standards. We have been, and will continue to be, primarily focused on higher education. But we have expanded our attention to include K-12 education, as it relates to preparing students for college. While our work has been largely on the College Board, and select aspects of high school education, this report is broader in its focus.

1 E.g., Tomáš Hudlický, "The Case of Tomáš Hudlický—Where now?" National Association of Scholars, August 3, 2020, https://www.nas.org/blogs/article/the-case-of-tomas-hudlickywhere-now.

We have broadened our focus to K-12 education because K-12 education has become extraordinarily nationalized in the last generation. A variety of nonprofit organizations have instituted overlapping educational standards since the year 2000, including the Common Core, the revised College Board Advanced Placement Standards, the C3 (College, Career & Civic Life) Framework for Social Studies State Standards, and the Next Generation Science Standards. These educational standards, promoted most notably by the Bill & Melinda Gates Foundation and the federal government, have sought to evade America's traditional and constitutional delegation of public education to the states and localities—delegated precisely so as to avoid a centralized straitjacket on American education. The federal government's financial incentives, combined with the bureaucratic evasion that *these are only standards, not curricula*, have created a *de facto* national curriculum, which limits school curriculum choice ever more tightly.

Proponents of these nationalized standards have on their side a seemingly powerful argument. Do the truths of algebra differ from Pensacola to Point Barrow? Does the dipole moment of H_2O differ from Maui to Maine? Does the speed of light in a vacuum vary depending on whether it is calculated in Phoenix or Philadelphia? If the findings of science, once validated, are taken to be timeless truths, shouldn't the curriculum by which young people are introduced to those findings likewise be fixed?

Yes, at least as far as we really have finality, or something very much like finality, on questions put before the sciences. But then the troubles begin—for a great deal of science is not "settled," and the whole point of genuinely scientific inquiry is to keep asking rather than to relax into reciting what we think we already know. Algebra can be taught in many ways. Its truths won't change, but the paths to those truths are many, and some perhaps remain undiscovered. Water is a more mysterious substance than its ubiquity would lead us to suppose. To teach its chemistry well, teachers must lead students to see water's manifold riddles. The speed of light is a "constant," but getting students truly to comprehend that concept requires more than merely memorizing a number.

For all these reasons, we prefer the pedagogy that isn't fixed like a fly in amber, but that instead is free to find its own paths in schools across the country.

There is another even more compelling reason to resist the one-size-fits-all approach to science instruction: one-size-fits-all inevitably means one mistake mars all. With a single standardized curriculum, we provide the pseudo-science ideologue and ignorant enthusiast with one-stop shopping. If they can get their favored hypothesis into a syllabus as "settled science," they can just as easily exclude any ideas that run counter to their hobbyhorses.

The nationalized K-12 curriculum inevitably influences higher education. America's colleges must teach students formed by this new nationalized K-12 system. Or rather, they must teach students who have failed to be educated by this new system. The new system fully justifies Americans' traditional suspicion of centralized systems of higher education, for it is both incompetent and politicized. America's colleges can only educate the graduates of incompetent K-12 schools by shifting from actual higher education to extensive remediation, at which they can achieve at best patchy success. The politicization of K-12 students reinforces the politicization of undergraduate education and makes it even harder for college professors to provide an education that aims at truth rather than propaganda. NAS must lend its weight toward K-12 education reform if it hopes to preserve undergraduate education.

This report focuses on the shortcomings of the Next Generation Science Standards (NGSS), which have already been adopted by twenty states and the District of Columbia. (A further twenty-four states have adopted science standards influenced by the NGSS's immediate predecessor, the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.)[2] The NGSS

2 "K-12 Science Standards Adoption," National Science Teachers Association, https://ngss.nsta.org/About.aspx.

are the most powerful force shaping American science education—and shaping it for the worse.

NAS has long been interested in the politicization of science. In the second issue of NAS's journal, *Academic Questions*, published in Spring 1988, NAS ran two articles that took strong exception with the quality of science in a report by the American Physical Society. One of the articles, written by Frederick Seitz, who was the former president of both the American Physical Society and the National Academy of Sciences, accused the Council of the American Physical Society of issuing a statement based on the report that abandoned "all pretense to being based on scientific factors." The report and the advocacy based on it (dealing with missile defense) were, in Seitz's view, "political" in nature.

In the years following the Seitz article, NAS took up a great variety of "academic questions." The integrity of the sciences was seldom treated as among the most pressing matters, but it was regularly examined, and NAS's apprehensions about misdirection in the sciences grew steadily. In 1992, Paul Gross contributed a keynote article, "On the *Gendering* of Science." In 1993, Irving M. Klotz wrote on "'Misconduct' in Science," taking issue with what he saw as an overly expansive definition of misconduct promoted by the National Academy of Sciences. Paul Gross and Norman Levitt presented a broader set of concerns in 1994, in "The Natural Sciences: Trouble Ahead? Yes." Later that year, Albert S. Braverman and Brian Anziska wrote on "Challenges to Science and Authority in Contemporary Medical Education." That same year NAS held a national conference on the state of the sciences. In 1995, NAS published a symposium based on the conference, "What Do the Natural Sciences Know and How Do They Know It?"

More recently NAS has published a small stream of articles on the topic, such as "Could Science Leave the University?" (2011) and "Short-Circuiting Peer-Review in Climate Science" (2014). When the American Association of University Professors published a brief report assailing the Trump administration as "anti-science," ("National Security, the Assault on Science, and Academic Freedom," December 2017), NAS responded with a three-part series, "Does Trump Threaten Science?" (To be clear, we are a non-partisan organization interested in promoting open inquiry, not in advancing any particular political agenda.) In the last few years, NAS has addressed the question of the irreproducibility crisis, in *The Irreproducibility Crisis of Modern Science: Causes, Consequences, and the Road to Reform* (2018)[3] and in our forthcoming report *Shifting Sands*, which examines governmental use of irreproducible science to make policy. We have also discussed the politicization of science education, as part of the broader politicization of undergraduate education, in *Social Justice Education in America* (2019).[4]

This report, *Climbing Down: How the Next Generation Science Standards Diminish Scientific Literacy*, extends that critique to K-12 science education. The authors establish first that the NGSS fail to meet what should be the basic prerequisites for a K-12 educational standard. They do not provide a science education adequate to take introductory science courses in college. They lack large areas of necessary subject matter and an extraordinary amount of mathematical rigor. They are, rather, what Ze'ev Wurman, an outspoken critic of the NGSS, rightly calls *science appreciation standards*.[5] The NGSS do not prepare students for careers or college readiness. Instead, they prepare students for remedial courses to make up for the inadequacy of their K-12 science education.

Climbing Down also establishes how deeply the NGSS's inadequacy is a result of their politicization. This is not merely a question of substituting climate-alarmist propaganda for science, abandoning the scientific method, neglecting the principle of falsifiability, making a cult of scientific consensus, substituting reliance on models for reliance on data and experiment, substituting process ("skills") for content knowledge, and adopting the professional assumptions of "Science, Technology, and

3 David Randall and Christopher Welser, *The Irreproducibility Crisis of Modern Science: Causes, Consequences, and the Road to Reform* (National Association of Scholars, 2018), https://www.nas.org/reports/the-irreproducibility-crisis-of-modern-science/full-report.

4 David Randall, *Social Justice Education in America* (National Association of Scholars, 2019), https://www.nas.org/reports/social-justice-education-in-america.

5 Ze'ev Wurman "Education to Raise Technology Consumers Instead of Technology Creators," Monolithic 3D, August 4, 2011, http://www.monolithic3d.com/blog/education-to-raise-technology-consumers-instead-of-technology-creators.

Society" (STS), a field which conceives of science as an exercise of power rather than a search for truth. Above all, the NGSS's politicization is the consequence of their commitment to *diversity and equity*. *Diversity and equity* justify incorporating the modern *diversity* cant into science education, substituting process knowledge, remedial communication skills, identity-politics hagiography, and political activism for actual content knowledge. *Diversity and equity* also justify diverting money from science education to an apparatus of remedial teachers and a penumbra of administrators and activists. The NGSS's commitment to *diversity and equity* is the single greatest contributor to their abandonment of adequate science standards.

I put this case more strongly than do the authors, who thoughtfully point out the occasional strengths of the NGSS, such as their incorporation of engineering into K-12 science standards. Their ability to point out the occasional good points of the NGSS strengthens their critique of the standards' weak points. On the whole, I think they are too generous. What the NGSS do right they do by meeting minimum professional standards, and that deserves no particular praise.

A word on the authors. Jennifer Helms and James Nations are the original authors of this report. They gave me a chance to read their first draft and I thought it should be sponsored by NAS. David Randall, NAS's director of research, took part in the revision process. His contribution eventually became large enough that he now has co-author status, although the core of *Climbing Down* remains the original work of Helms and Nations. I am delighted that Helms and Nations agreed that NAS should sponsor their work and am proud that NAS staff could contribute to it as well.

Climbing Down closes with a series of policy recommendations to depoliticize K-12 science education and improve its rigor. Above all, state education departments should abandon the NGSS for more rigorous science standards. All these recommendations are well-advised. Readers should keep in mind the stakes. It is not just the future of American science education—although that would matter in itself. It is the future of American science, upon which rests much of our nation's prosperity, as well as our ability to compete with strategic rivals such as China. American science cannot continue to prosper if it must rely exclusively on foreign students and professors fortunate enough to have been educated free of the crippling dogmas of American science education.

America now suffers from large-scale scientific espionage by China.[6] The silver lining is that the Chinese judge we have science worth stealing. The NGSS will strip America of its heritage of technological and scientific triumph. If America continues to use the NGSS, we will no longer suffer from foreign espionage because we will possess no knowledge anyone else wants to know.

6 David Acevedo, "Cracking Down on Illegal Ties to China," National Association of Scholars, January 15, 2021, https://www.nas.org/blogs/article/cracking-down-on-illegal-ties-to-china.

Introduction

Introduction

America built its strength and its prosperity on K-12 science education. Our public schools provided the first science education to a host of extraordinary American scientists. Nobel Prize-winning physicist Richard Feynman learned about atoms in Far Rockaway High School in Queens, New York. Linda Buck, who won her Nobel Prize in Physiology, learned biology at Roosevelt High School in Seattle, Washington. Apple founder Steve Jobs learned electronics in Homestead High School in Cupertino, California. Millions of Americans work in science, technology, and industry, thanks to the solid science education they received in public schools.

Today, American science education is under assault. Education "reformers" who dislike rigor and rich content dislike any proper science education—because scientific reasoning cannot be taught without rigor and rich content. Contemporary academics hostile to America's European roots have contributed to this disdain of science, since the history of science is a uniquely European triumph. Politicized activists also eschew unfettered scientific inquiry in favor of rote answers on subjects such as climate change. Indeed, the latest generation of science education reformers has replaced scientific content with performance-based "learning" activities, and the scientific method with social consensus.

The Next Generation Science Standards (NGSS) have done more to degrade American K-12 science education than any other "education reform" in the last generation. This report will outline how the NGSS, a mediocre-to-incompetent set of national science standards, channel politically-charged, flawed science into American public education—science so badly taught that high school graduates will be unprepared for introductory college science courses. The NGSS will make it impossible for America to educate its next generation of scientists. It poses a clear and present danger to America's strength and prosperity.

A History of Science Education

A History of Science Education

A Nation at Risk

American education deteriorated between 1960 and 1980, as evidenced by falling test scores across the nation. By this time, progressive education had been in full force, inculcating an entire generation of school children with radical ideologies. What is known as the Great American Test Score Decline during these two decades led the Reagan administration's National Commission on Excellence in Education to publish its 1983 report, *A Nation at Risk*.[7] This report warned of the dangerous deficiencies within American education, which could lead to a loss of American leadership in commerce, technology, and science.[8]

In the years since *A Nation at Risk*, American schools have been viewed as failing, a diagnosis that led to their subsequently being trapped in the struggles of standards-based education. More than thirty years later, we have the Common Core State Standards (CCSS) for mathematics and English language arts (ELA) and the promises of "college- and career-readiness," as if these goals were somehow not met for American schoolchildren before the federal government supplanted traditional district-led education with standards- and assessment-driven teaching. Not surprisingly, the national replacement of science standards was not far behind.

7 *A Nation at Risk*, National Commission on Excellence in Education, 1983, https://www2.ed.gov/pubs/NatAtRisk/risk.html.

8 Robert J. Franciosi, *The Rise and Fall of American Public Schools: The Political Economy of Public Education in the Twentieth Century* (Westport, Connecticut: Prager, 2004).

Origins of the NGSS

In 2007, the Carnegie Corporation and the Institute for Advanced Study created the Commission on Mathematics and Science Education, which called for a common set of science standards in American K-12 education. Their 2009 report, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy,* recommended the following: (1) produce common science and math standards with aligned assessments; (2) establish partnerships between the K-12 education system and universities, non-profit and philanthropic organizations, and the business sector; and (3) create longitudinal data and accountability systems for research to change policy and practice in education.[9] The common set of mathematics standards recommended by the commission was already in development, published as part of the CCSS in 2009. The new science standards blueprint, *A Framework for K-12 Science Education,* was published shortly afterward in 2011 by the National Research Council of the National Academy of Sciences and provided the foundation for the NGSS.

The Next Generation Science Standards (NGSS)[10] were released in April 2013 and, to date, have been adopted by twenty states and the District of Columbia. They were developed by a partnership of four entities, including the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and the leader of this education-reform scheme, Achieve, Inc., the Washington, D.C.-based trade association that also took the lead in formulating the CCSS.

The NGSS are not officially part of the CCSS, which include English language arts and mathematics standards; however, the NGSS were

9 Commission on Mathematics and Science Education, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy* (Carnegie Corporation of New York and Institute for Advanced Study, 2009), pp. viii-ix, 8, https://production-carnegie.s3.amazonaws.com/filer_public/80/c8/80c8a7bc-c7ab-4f49-847d-1e2966f4dd97/ccny_report_2009_opportunityequation.pdf.

10 *Next Generation Science Standards: For States, by States* (National Academies Press, 2013), https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states.

written to align with the CCSS, as noted in the NGSS document.[11] Note also that the CCSS ELA standards encourage teachers to inject science content into their "English" lessons—the official title of the standards includes "Literacy in History/Social Studies, Science, and Technical Subjects."[12] The NGSS's alignment with the CCSS is found in the bottom section of each table labeled "Common Core State Standards Connections" on each standard page.

Despite their impressive title, the NGSS are nothing more than a set of mediocre science standards that have not been vetted, were never piloted or otherwise tested, and reveal an overt political agenda embedded in K-12 science education that parents, educators, and the public should find troubling. The NGSS have distinctly different priorities from those of previously published K-12 science standards. Engineering, environmental science, evolution, and climate change are given a much more prominent role in the NGSS compared to individual state standards around the nation.

11 Ibid., p. xiii.

12 *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects* (Common Core State Standards Initiative, 2010), http://www.corestandards.org/wp-content/uploads/ELA_Standards1.pdf.

The Design of the Standards

The Design of the Standards

A Model of Mediocrity

In June 2013, the Thomas B. Fordham Institute published its *Final Evaluation of the Next Generation Science Standards*[13] document, which compared the NGSS with 55 other sets of science standards, including those from all 50 states and the District of Columbia, as well as four non-state sets of standards written by the Program for International Student Assessment (PISA), American College Testing (ACT), Trends in International Math and Science Study (TIMSS), and National Assessment of Educational Progress (NAEP), respectively. Fordham's mission is to promote educational excellence for every child in America through "quality research, analysis, and commentary,"[14] and it is the foremost organization in the country that rates state science standards. Notably, Fordham has also been an enthusiastic proponent of the Common Core standards (perhaps because of its lavish funding from Common Core financier, the Bill and Melinda Gates Foundation). But even Fordham could not overlook the serious errors and inadequacies within the NGSS.

Fordham gave each set of standards a grade of A, B, C, D, or F; a numeric score of 0 to 10; and a relative quality comparison with the NGSS as "clearly inferior," "too close to call," or "clearly superior." The authors used "substantially the same criteria as [they] previously applied to state science standards—criteria that focus primarily on the content, rigor, and clarity of K-12 expectations for this key subject."[15] Based on these criteria, they ranked the NGSS 26th out of 56 standards, with a grade of "C" and a numeric score of 5 out of 10. In Fordham's assessment,

13 Paul R. Gross, et al., *Final Evaluation of the Next Generation Science Standards* (Thomas B. Fordham Institute, 2013), https://fordhaminstitute.org/national/research/final-evaluation-next-generation-science-standards.

14 Thomas B. Fordham Institute Mission," https://fordhaminstitute.org/about.

15 Gross, "Final Evaluation," p. 2.

the NGSS are nothing more than mediocre in the world of state science standards.

The "C" grade by Fordham was based primarily on the issue of inadequate content. According to the report's forward:

> *First*, missing and "implicit" content. Pruning and prioritizing can be taken too far, and it does nobody any favors to pretend to omit content from one grade that later turns out to have been essential. Yet the NGSS sometimes does precisely that: it never explicitly requires some content in early grades that is then assumed in subsequent standards.

> This problem is especially visible in the earth and space science section, where (in the review's words) "so much implied content is inferred in a single statement that it is difficult to imagine just what one might expect to be taught."[16]

The specific standards in the NGSS identify what "students who demonstrate understanding" can accomplish. Unfortunately, the NGSS will not help students prepare for careers in any field, STEM (science, technology, engineering, and math) or otherwise; rather, it will be a severe hindrance to gaining even basic knowledge and understanding of critical science concepts. A bold claim? Not at all, if you read the NGSS and the comments from Fordham.

It is puzzling that some states with standards ranked as "superior" or "clearly superior" to the NGSS, in both grades and numeric scores, have cast aside those superior standards to endorse the NGSS. How can it be prudent to discard "clearly superior" standards and adopt newer, lower-ranked standards that have no research evidence to support them? Apparently, the dazzling appeal of shiny new standards trumps substance.

16 Ibid., p. 8.

Equally perplexing is that some states with lower standards have chosen to adopt a new set of C-graded standards, rather than look to the states ranked in the top ten for superior standards upon which to base their revisions. If states with lower-ranked science standards wish to improve, they would be wise to consult those superior standards in correcting deficiencies.

Three-Dimensional Learning

The National Research Council's document *A Framework for K-12 Science Education*,[17] upon which the NGSS are based, outlines three "dimensions" for science education: Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Using these three dimensions in an integrated fashion is referred to as "three-dimensional learning."

Definitions:

- Practices – What we would typically refer to as "skills."
- Crosscutting Concepts – Seven concepts identified that link ideas and practices across various science disciplines (for example, "cause and effect" might be discussed when studying earth and also when studying heredity).
- Disciplinary Core Ideas – General headings for the standards in the NGSS document, beneath which specific standards are located.[18]

This structure may seem somewhat confusing, as traditional K-12 science education standards typically organize content into two major categories: theory (called "core ideas" in the NGSS) and practice (called "practices" in the NGSS). The NGSS document claims to have a smaller set of core ideas with a focus on deeper understanding and application

17 National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Washington, D.C.: National Academies Press, 2012), National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Washington, D.C.: National Academies Press, 2012), https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.

18 Ibid., pp. 30-34.

of science knowledge.[19] The "smaller set of core ideas" is certainly true, as a great deal of content is missing; however, the "deeper understanding" of science knowledge remains to be seen.

The consequence of fusing process and content into three-dimensional learning is a bizarrely excessive concentration on practices, at the expense of content knowledge.

> Unfortunately, the NGSS suffer from the belief—widespread among educators—that practices are more important than content. Consequently, every standard in the NGSS articulates a practice first, even when doing so obscures the content that students should learn. And while there are stand-alone standards that list practices and skills that students must master, there are no stand-alone expectations that list—in clear, teacher-friendly language—the content that students should learn. Throughout the NGSS, content takes a backseat to practices, even though students need knowledge before they'll ever demonstrate fluency or mastery of scientific processes.[20]

In so doing, the NGSS ignore the insights of E. D. Hirsch that content knowledge is essential for gaining any sort of practices/inquiry skill.[21] Additionally, *teaching to the test* means that, when you replace content knowledge with process knowledge, the content knowledge will never get taught, no matter how often you stipulate that teachers and students can "optionally" go on to more advanced study.

19 Ibid., p. 31.

20 Gross, "Final Evaluation," p. 12.

21 E. D. Hirsch, *The Knowledge Deficit: Closing the Shocking Education Gap for American Children* (New York: Houghton Mifflin, 2006). See also Laeora Berkson, "Problem-Based Learning: Have the Expectations been Met?" *Academic Medicine* 68, Suppl (1993): S79-S88, DOI: 10.1097/00001888-199310000-00053; Jerry A. Colliver, "Effectiveness of Problem-Based Learning Curricula: Research and Theory," *Academic Medicine* 75, 3 (2000): 259-66, DOI: 10.1097/00001888-200003000-00017; Nelson Cowan, "The Magical Number Four in Short Term Memory: A Reconsideration of Mental Storage Capacity," *Behavioral and Brain Sciences* 24, 1 (2000): 87-114. Nelson Cowan, "Mental Objects in Working Memory: Development of Basic Capacity Or of Cognitive Completion?" *Advances in Child Development and Behavior* 52 (2017): 81-104, DOI: 10.1016/bs.acdb.2016.12.001; E. D. Hirsch, "'You can always Look it Up'...Or can You?" *American Educator* 24, 1 (2000): 1-5, https://www.aft.org/sites/default/files/periodicals/LookItUpSpring2000.pdf.

Adoption of the NGSS

To date, twenty states plus the District of Columbia have adopted the NGSS, and an additional twenty-four states have developed new science standards using the National Research Council's (NRC's) *A Framework for K-12 Science Education*. **(See Table 1.)**

Table 1: NGSS Adoption [22]

States that have adopted the NGSS, including the District of Columbia:	States that have developed new K-12 science standards using the basis for the NGSS, the NRC Framework for K-12 Science Education:
Arkansas	Alabama
California	Alaska
Connecticut	Arizona
District of Columbia	Colorado
Delaware	Georgia
Hawaii	Idaho
Illinois	Indiana
Iowa	Louisiana
Kansas	Massachusetts
Kentucky	Minnesota
Maine	Mississippi
Maryland	Missouri
Michigan	Montana
Nevada	Nebraska
New Hampshire	New York
New Jersey	North Dakota
New Mexico	Oklahoma
Oregon	South Carolina
Rhode Island	South Dakota
Vermont	Tennessee
Washington	Utah
	West Virginia
	Wisconsin
	Wyoming

22 "K-12 Science Standards Adoption," National Science Teachers Association, https://ngss.nsta.org/About.aspx"K-12 Science Standards Adoption," National Science Teachers Association, https://ngss.nsta.org/About.aspx.

The Problem of Clarification Statements

NGSS writers and supporters claim that the NGSS "are standards, not curriculum,"[23] and that the specifics of education will remain within the purview of local districts and classroom teachers; however, the structure of the NGSS belies that claim. Ninety-two percent of the NGSS (176 of the 191 standards) include a "clarification statement" which provides numerous examples of activities that students "could" and "should" engage in to "demonstrate understanding."[24] The prevalence and content of "clarification statements" are akin to requiring these and only these curricula and activities. Thus, the specifics of education will reside not in local districts but in the NGSS and the associated testing/assessments. Additionally, many clarification statements contain errors in facts, errors in concepts, and blatant political indoctrination.

<u>Example of clarification statement with errors in fact or concept:</u>

> K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

> [Clarification Statement: Examples of patterns could include that **animals need to take in food but plants do not**, the different kinds of food needed by different types of animals, the requirement of plants to have light, and that all living things need water.][25] [Emphasis added]

This clarification statement is poorly written and simply incorrect. Plants need carbon dioxide (CO_2) and a variety of nutrients as "food," a basic concept that should be taught at this age. This is a kindergarten

23 *Next Generation Science Standards*, p. xiv.
24 Ibid.
25 Ibid., p. 167.

standard, but young children are capable of understanding that plants require nutrition just like humans and animals.

Example of clarification statement substituting for curriculum:

> 3-PS2-3. Ask questions to determine cause and effect relationships of electrical or magnetic interactions between two objects not in contact with each other.

> [Clarification Statement: Examples of an electrical force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paper clips, and the force exerted by one magnet versus force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.][26]

This extremely detailed clarification statement raises the question: Do competent classroom teachers require a clarification statement to teach to the standards? This same type of clarification also prevails in the Common Core State Standards through the use of both implementation documents and extensive teacher training. The reason for such detailed instructions for teachers is unclear. A professional in the workplace, bringing appropriate knowledge, skills, and experience as an educator, should not require prompts or suggestions to develop students' understanding.

In reality, such prompts are necessary only for teachers neither knowledgeable nor skilled in science education. Dependence on what

26 Ibid., p. 25.

the NGSS have put forth is then instilled and perpetuated, essentially the "world according to the NGSS." This amounts to broad-spectrum indoctrination and a subsequent loss of local initiative and control.

Limitations Posed by Assessment Boundaries

The NGSS's Introduction states that, "the NGSS do not dictate nor limit curriculum and instructional choices."[27] We have already seen how clarification statements belie this claim. Another facet of the NGSS that operates to control what is taught in the classroom is the use of "assessment boundaries."

An assessment boundary is a statement of what is *not included on the test.* Sixty-six percent of the NGSS (127 of the 191 standards) include assessment boundaries, which were designed to inform testing companies for the development of future assessments. To date, there are no operational NGSS-aligned assessments; they continue to be designed and field-tested. The emphasis on performance rather than content in the NGSS will make standardized testing a challenge. It remains unclear how teachers can adequately or fairly evaluate a student's knowledge on a standardized test when the classroom focus is on hands-on performance rather than content knowledge. The Every Student Succeeds Act (ESSA)[28] requires science testing once during each of a student's elementary, middle, and high school years. The only way to meet this federal requirement is for states now using the NGSS to continue utilizing science assessments that are aligned with their previous state standards.

Realistically, in an educational system fraught with an over-reliance on standardized testing to "grade" teachers as well as students, it only makes sense that educators will spend most of their time "teaching to the test." Consequently, if a standard specifically states that a concept

27 Ibid., p. xiv.

28 *Every Student Succeeds Act*, 20 U.S.C. ch. 28 § 1001 et seq. 20 U.S.C. ch. 70, (2015), https://www.ed.gov/essa?src=rn.

is not on the test, it will likely not be taught in the classroom, or, if it is included in the lesson plan, it will not be given priority, thus limiting the depth and breadth of what is taught for that standard. This poses a significant problem for true science education, because much of the content limited by assessment boundaries is crucial for understanding concepts that are foundational for future college-level science courses.

Examples of content limited by an assessment boundary:

Example #1

> HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

> [Assessment Boundary: Assessment does not include identification of **specific cell or tissue types, whole-body systems**, specific protein structures and functions, or the biochemistry of protein synthesis.] [Emphasis added] [29]

In this assessment boundary, we find that cell and tissue types and whole-body systems will not be tested. Indeed, whole-body systems are found nowhere in the high-school life science standards—a significant omission.

Example #2

> 5-PS1-3. Make observations and measurements to identify materials based on their properties.

> [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals,

29 *Next Generation Science Standards*, p. 105.

> minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.]

> [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.][30]

Fifth-grade students are significantly hindered by this assessment boundary. Ignoring the relationships between hardness and density, as well as the difference between mass and weight, is akin to educational malfeasance for this age.

Assessment boundaries result in major deficiencies in the NGSS. Typically, state standards (previous to the NGSS) do *not* specify what is *not* on a test, so we question the reason for including this type of delineation in the NGSS. Although many teachers will teach to the test, we expect a few dedicated science teachers will forge ahead with their higher-quality teaching and continue to help students master the science concepts critical to future collegiate science courses. Unfortunately, assessment boundaries ensure that, in too many cases, the opposite will occur.

30 Ibid., p. 43.

The Omissions and Inadequacies of the Standards

The Omissions and Inadequacies of the Standards

Inadequate Mathematics Preparation

Mathematics is used in all scientific disciplines to measure, quantify, calculate, and predict; hence, mathematics is called the language of science. It is no coincidence that significant advances in mathematics and the sciences were made around the same time during the 17th and 18th centuries. The two are inextricably linked. For example, astronomy reveals that planets orbit around the sun obeying mathematical laws. Kepler's *Harmony of the Heavens*, his theory of celestial harmony, was expressed in mathematical terms, as was Newton's formula for gravity. Today, mathematics is used extensively in all of the scientific disciplines, in both laboratory and applied forms. STEM-bound students need a firm grasp on high-level mathematics in order to compete academically and enter STEM fields; in fact, they need to be ready for advanced calculus when they arrive on the college campus.

Common Core mathematics standards, unfortunately, pushed Algebra I from the 8th grade into the 9th, making it far less likely for a student to complete calculus by the end of high school. STEM-bound students need to be considerably further beyond Algebra II and Geometry by the time they start their college coursework.[31] This push of upper-level math into the higher grades is perplexing, as the National Mathematics Advisory Panel referred to the 8th-grade placement of algebra as "rigor" in its 2008 report.[32] That same year, the Common Core's *Benchmarking for Success* report[33] recommended that Algebra I be started in the 8th grade. Yet despite these clear recommendations, the CCSS

31 Ze'ev Wurman, "Why Students Need Strong Standards [and Not Common Core]," American Principles Project, https://appfdc.org/wp-content/uploads/2017/05/Math-Standards-Problems-with-Common-Core.pdf.

32 National Mathematics Advisory Panel, "Foundations for Success: The Final Report of the National Mathematics Advisory Panel," U.S. Department of Education, 2008, https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf.

33 National Governor's Association, Council of Chief State School Officers and Achieve, Inc., "Benchmarking for Success: Ensuring U.S. Students Receive a World-Class Education," National Governor's Association, 2008, http://www.corestandards.org/assets/0812BENCHMARKING.pdf.

math standards, published a year later, placed Algebra I in the 9th grade. This hinders achievement in rigorous secondary-level science standards, especially physics and engineering, which require a firm grasp of pre-calculus and calculus. This means that STEM-bound students will enter college lacking completion of important mathematics *and* science coursework in their secondary education.

Fordham's review of the NGSS identified the lack of math content as yet another weak and undesirable component of the standards. Indeed, in line with the problems created by questionable content, clarification statements, and assessment boundaries, math education is not only missing in the NGSS; it has been replaced by a preference for subjective judgment in critical areas. However, if the NGSS and CCSS are supposed to be superior to previous standards, we question why these standards would delay the desirable early (and frequent) exposure to math tools.

Chemistry and Physics

The most obvious gaps in the NGSS are found in the high-school (grades 9-12) standards. The paucity of chemistry standards would not justify even a basic, one-semester high-school chemistry course. Physics is all but completely absent, with the occasional rudimentary nod to a physics principle. The reason for the absence of physics is unclear. The more advanced physics content, such as what would be found in an advanced placement (AP) physics course, would require mathematics beyond algebra such as pre-calculus and calculus, which CCSS does not provide. The NGSS promise deeper insight and understanding, yet by avoiding the more advanced mathematics courses in CCSS, it actually promotes a simplistic and disjointed study of physics that cannot serve as a stepping stone to further study. While this does not necessarily hurt students who will continue to study humanities, it definitely holds back STEM-going students.[34]

34 Ze'ev Wurman, personal communication, January 12, 2021.

Life Science

The life science standards lack a considerable amount of biology. Some omissions are a consequence of assessment boundaries, while others are obvious, intentional exclusions.

Omissions in the life science standards include:

- Whole-body systems
- Cell and tissue types
- Cellular feedback mechanisms
- Protein structure and function
- Cell division (mitosis and meiosis)
- Bacteria
- Virus
- Taxonomy (and its specific terms domain, kingdom, phylum class, order, family, genus)
- Ribonucleic acid (RNA)
- Deoxyribonucleic acid (DNA)
- Endothermic
- Exothermic
- Capillary
- Recessive genes
- Dominant genes

Physical Science

Physical science fares no better. A standard physical science course, typically offered in the 9th-grade year, would include a great deal more material than that which is found in the NGSS. So much is missing, in fact, that there is not enough content for what used to be a one-year physical science class. Perhaps the reason for this omission is that this content is the prerequisite to the now nearly nonexistent chemistry and physics course standards. It is no surprise that physical science concepts are so sparse—they are assumed to be unnecessary.

Omissions in the physical science standards include:

- Lab safety
- Newton's first law
- Energy
- Thermodynamics
- Ohm's law
- Simple electrical circuits
- Venturi
- Inertia
- Optics
- Spectrum
- pH scale
- Acid
- Alkaline
- Electricity is mentioned twice, but basic common technological terms such as voltage, resistance, and watt are missing
- Axle
- Wheel
- The basics of simple machines such as inclined planes, levers, pulleys, screws, wedges, compression, tension, and batteries
- Radar
- Sonar
- Magnetism
- Computer science terms such as program, code, bit, byte, robot, laser, GPS, and 3-D printing

Earth and Space

The Fordham review of the NGSS considered the earth and space science section of the standards rather ambitious, with an exhaustive list of concepts to be covered, some without adequate background from earlier grades. Unfortunately, important topics were left out and replaced with climate change.

Omissions in the earth and space standards include:

- Triassic period
- Jurassic period
- Cretaceous period
- Continental drift
- Igneous
- Metamorphic
- Aeolian
- Alluvial
- Hydraulic
- Artesian
- Lava
- Magma
- Pyroclastic
- Strike
- Slip
- Hadley cells
- Milankovitch cycles
- Precession
- Names of planets, and space-specific terms such as asteroid, astronomy, comet, corona, nucleus, Oort cloud, and satellite (mentioned once)

Not surprisingly, the NGSS authors could not find room to discuss such rudimentary concepts as we have listed, but *climate change, global warming, human impacts, severe weather,* and other politically charged terms appear dozens of times.

The Addition and Deficiencies of Engineering Standards

To their credit, the authors of the NGSS have added the subject of engineering to introduce students to a discipline to which they had little exposure with previous standards, unless they opted to enroll in a high-school physics course. However, a substantial disconnect exists between the high-school engineering standards and the essential math and physics content that will allow a student to grasp engineering concepts. Without the requisite physics content, engineering can only be given a cursory nod. Likewise, the delay of algebra to grade nine in the Common Core mathematics standards results in pushing higher-level math so late into high school that vital trigonometry and calculus understanding is missing when a student learns high school-level engineering. In fact, the science and engineering practices for the high-school engineering standards specify that students must use trigonometric functions, which are nowhere to be found in Common Core math.

This misalignment results in nothing more than an "engineering appreciation" class, rather than a course in which students engage in the mathematical computations required in real engineering. The NGSS's claim to teach students engineering is thus exposed as deliberate misinformation.

The NGSS's engineering component consists overwhelmingly of "global issues" such as environmentalism and social welfare, rather than any preparation for building bridges, offshore oil rigs, fiberglass, electronics, or space elevators.[35] Neither does it mention that

35 *Next Generation Science Standards*, Appendixes, p. 106.

engineering might be dedicated to the national interest by work for the American military. The NGSS suggest engineering assignments such as "Evaluate competing design solutions for maintaining biodiversity and ecosystem services."[36] As Gross *et al.* note, "the only engineering and technology evident in that section is associated with biodiversity and ecosystem management, or with ethical issues bearing on genetic modification of organisms."[37]

NGSS engineering is not, in any case, the highly technological and demanding engineering that is the pride of America, but a more general cast of mind.

> We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. Likewise, we broadly use the term "technology" to include all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants. ... The term "engineering design" has replaced the older term "technological design," consistent with the definition of engineering as a systematic practice for solving problems, and technology as the result of that practice.[38]

The NGSS fail to follow up this introduction with any sustained coverage of the rigors of technological design. This vitiates much of the utility of introducing engineering standards at all.

The NGSS repeatedly emphasize "social" constraints:

36 *Next Generation Science Standards*, p. 70; and see pp. 85, 125, 128-29; *Framework*, pp. 70-71.
37 Gross, "Final Evaluation," p. 51.
38 *Framework*, pp. 11–12, cited in *Next Generation Science Standards*, Appendixes, p. 103; *Next Generation Science Standards*, Appendixes, p. 103.

> It is up to the designer to try to anticipate the effects it may have and to behave responsibly in developing a new or improved technology. These considerations may take the form of either criteria or constraints on possible solutions.[39] … Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.[40] … When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.[41]

The NGSS thereby strongly suggest that the point of engineering is to satisfy the shackles of the regulatory state.[42] Even where the state does not intervene, the NGSS's attitude toward engineering is dully cautious and utilitarian: "Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks."[43] The NGSS provide no sense of those heroic engineers who have sought to instill design with both excellence and beauty—Isambard Kingdom Brunel and his dedication to great and beautiful railways and ships, Steve Jobs and his design of Apple products, the Fort Peck Dam spillway that Margaret Bourke-White photographed in 1936 for the cover of the first issue of *Life*.

The NGSS scarcely prepare students for engineering, and not at all to build something innovative, something beautiful, some machine that is simply and wonderfully best suited for its task.

39 *Next Generation Science Standards*, p. 85.
40 Ibid., p. 95.
41 Ibid., p. 127.
42 And see *Framework*, pp. 202-03, 205-06, 209-10, 213.
43 *Next Generation Science Standards*, p. 101; and see *Framework*, p. 48.

The Scientific Method

The most conspicuously absent concept is the ***scientific method.*** This omission alone should alarm anyone concerned with the quality of K-12 science education and the future of science in general. The scientific method is the logical and rational process through which we observe, describe, explain, test, and predict phenomena. While the scientific method is not always an identical, linear, step-by-step process, and qualitative research admittedly relies on subjective observation, science still relies on established methods by which to inquire, and then collect and analyze data to generate reproducible results. Unfortunately, the scientific method is nowhere to be found in the actual standards of the NGSS; instead, it is merely given a nod in the NGSS appendices.

The NRC *Framework for K-12 Science Education* states that "a focus on practices (in the plural) avoids the mistaken impression that there is one distinctive approach common to all science—a single 'scientific method.'"[44] This amounts to an assertion that method is not really needed; however, scientists *do* use established methods. There is a process for finding answers to scientific questions. The number of steps may change from one investigation to the next, and there may be movement back and forth between those steps, but there is always a general method to follow. For example, not every investigation requires that a hypothesis be tested; some studies are developed around a question without a hypothesis. And deciding on the exact type of data to be collected depends on first refining the research question, since valid answers cannot be found if appropriate data have not been collected due to an ambiguous question. This is an important lesson that should be taught to students in science education: method is important, but the steps and the way you shift between them depends on the type of inquiry in which you are engaged. Unfortunately, rather than explain or demonstrate to students that scientific investigations may differ based on the research

44 *Framework*, p. 48.

question at hand, the writers of the NGSS simply throw out the scientific method altogether.

Their omission of the scientific method is inconsistent with a later statement in the same *Framework* document, which reads, "epistemic knowledge is knowledge of the constructs and values that are intrinsic to science. Students need to understand what is meant, for example, by an observation, a hypothesis, an inference, a model, a theory, or a claim and be able to readily distinguish between them."[45] The NGSS and their *Framework* leave unexplained how students can learn these concepts without reference to the scientific method, or why they should bother. The NGSS oddly directs students to "Make observations (firsthand or from media) to collect data that can be used to make comparisons."[46] The idea that a newspaper or internet article should count as *observations* or *data*, when it can as easily contain a popular delusion presented as scientific truth, should not be entertained at any level of science pedagogy.

This leaves us with two questions: (1) how does one teach these examples of "constructs and values intrinsic to science" without explaining the scientific method and deductive reasoning that have been relied upon by scientists for centuries, and (2) how can students learn to distinguish between theory, model, and evidence if they cannot grasp the methods and reasoning through which theories and models have been developed?

The *Framework* makes this astonishing statement:

> a focus on practices (in the plural) avoids the mistaken impression that there is one distinctive approach common to all science – a 'scientific method.' ... the notion that there is a single scientific method of observation, hypothesis, deduction, and conclusion—a myth perpetuated to this day by many textbooks—is fundamentally wrong. Scientists

45 Ibid., p. 79.
46 *Next Generation Science Standards*, p. 5, and see pp. 6-8, 10, 12-14, 19; and see *Framework*, p. 62.

> do use deductive reasoning, but they also search for patterns, classify different objects, make generalizations from repeated observations, and engage in a process of making inferences as to what might be the best explanation. Thus the picture of scientific reasoning is richer, more complex, and more diverse than the image of a linear and unitary scientific method would suggest.[47]

This assertion is false. Every scientist knows that the scientific method is not a mechanical procedure, and that qualitative research frequently relies on necessarily subjective observations. Every scientist also knows that each discipline and question require thought about *how* to use the scientific method for the inquiry at hand. Yet science still relies on the scientific method, which is indeed distinct from all other methods that inquire into truth, as the basic approach by which to inquire, collect, and analyze data, and thereby generate reproducible results. The NGSS fail to teach this fundamental concept.

The NGSS's glancing mentions of the scientific method, moreover, obscure crucial aspects of scientific claims to truth—that they must be *falsifiable* and *replicable*.[48] The NGSS state that scientific research and theories can be *modified, reinterpreted,* and *revised*, but it never states explicitly that even a theory with a mountain of apparent evidence can be *refuted*—and that a proper scientist will take a convincing refutation as a reason to discard a theory rather than to modify it.[49] The NGSS do not teach students that innovative scientists can create *paradigm shifts* that upend old scientific worldviews.[50]

Neither the *Framework* nor the NGSS ever use the words *falsifiable* or *falsifiability* or convey any sense that evidence that fits an unfalsifiable theory has no scientific validity. Neither do *Framework* or the NGSS hint

47 *Framework*, pp. 44, 78.

48 Karl Popper, *The Logic of Scientific Discovery* (New York: Routledge, 2002); Erwin B. Montgomery, Jr., *Reproducibility in Biomedical Research: Epistemological and Statistical Problems* (Cambridge, MA: Academic Press, 2019).

49 *Next Generation Science Standards*, pp. 82, 96, 102.

50 Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1996).

at the *irreproducibility crisis*—of whose existence all citizens and practicing scientists ought to be aware.[51] Instead (as noted above) they add, unjustifiably, the idea that the 'validation' of 'the science community' is some part of the development of scientific theory.[52] The NGSS oddly present the idea that the scientific community should have great authority, when such authority as they rightly possess derives from the willingness to submit themselves to the rigor of the scientific method—the existence of which the NGSS deny.

The NGSS's shift from the scientific method to 'scientific practices' makes possible both the elimination of key elements of the scientific method and the insertion of elements that have nothing to do with the scientific method.

The Cult of Consensus

Proponents of the NGSS often claim that science is "fundamentally a social enterprise"—a phrase found multiple times in our research on the NGSS—meaning that method is insignificant and learning science through teamwork is imperative. We agree that scientists do not work in isolation; rather, they engage in collaboration with others at each stage of inquiry, from initial questions and observations to peer review and dissemination of findings. Indeed, a team approach can be appropriate in science education activities, and it makes learning fun. Science projects are often more enjoyable with a group. However, leaving out any mention of method or the forms of scientific reasoning (inductive, deductive) is akin to throwing the baby out with the bathwater.

It is not unreasonable to predict that removing the scientific method will eventually eliminate intellectual scaffolding, producing a community of pseudoscientists who "feel" their way to answers through social

51 David Randall and Christopher Welser, *The Irreproducibility Crisis of Modern Science: Causes, Consequences, and the Road to Reform* (New York: National Association of Scholars, 2018), https://www.nas.org/reports/the-irreproducibility-crisis-of-modern-science.

52 *Next Generation Science Standards*, p. 121; and see *Framework*, p. 27.

and emotional activity, often relying on consensus rather than data and the reliability of evidence. Without a consistent, systematic, and dependable method of scientific inquiry, the search for empirical evidence becomes nothing more than a game of subjective relativism where the loudest "player" or the most populous "team" claims victory with their "answer" to the question.

The new catechism of the NGSS is (1) do not question underlying assumptions found in the standards, and (2) treat consensus as equal in value to empirical data. This is by design. Creating a generation of citizens who bow to consensus reduces worry that scientists and science professors—those in the future academy—will dare to research and report any findings that will put them at odds with the political and academic machine. The result will not be the formation of scientists but good marching soldiers who do not challenge the consensus. Already, the stories of scientists who have been bullied and stripped of their good reputation are abundant.[53] These days it is professionally dangerous to ask the politically incorrect question, find the truth, and report it. An inability to reason with evidence and facts harms a free society.

Overreliance on Models

Aside from the absence of the scientific method, clear evidence of disregard for empirical evidence is found in the NGSS's overriding dependence on models. A search for "model" or "modeling" produces over 500 mentions throughout the NGSS document. A similar search for "experiment" or "experimental" results in 14 and eight results, respectively. At the middle-school and high-school levels, model-based standards constitute 27 percent of the total. Models are theoretical in nature; they are testable ideas based on observations and can be helpful in science education for understanding conceptual relationships and phenomena.

53 David Acevedo, "Tracking Cancel Culture in Higher Education," National Association of Scholars, January 12, 2021, https://www.nas.org/blogs/article/tracking-cancel-culture-in-higher-education.

Models do not, however, constitute verifiable evidence. They cannot and should not be used as a substitute for empirical evidence within scientific enterprise or in science education standards.

There are many situations when using models is sensible. The issue is that students do not understand the inadequacies of a scientific model compared to empirical evidence that can be verified and reproduced. The overreliance on models in lieu of observable and verifiable data leads to the repeated acceptance of errors and incorrect conclusions as fact. It is unacceptable for science standards to endorse models to the exclusion of the scientific method.

There is no mention of mathematical equations in the high-school level standards for modeling, so we question the depth of modeling that students could accomplish. Perhaps the NGSS writers believed that simple diagrams, charts, or graphs would suffice; however, simple expectations like these do not deliver the high level of rigor in science education we should expect.

Partly this is a sleight of hand: it is meant to connote learning how to draft (say) airplane design models on a computer,[54] whereas it actually provides basic process instruction for *diversity* purposes. It also works hand-in-glove with the "climate science" propaganda:

> Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.[55]

The NGSS generally teach students to have faith in computer models, rather than regarding them as tools that require rigorous training

54 *Next Generation Science Standards*, Appendixes, p. 17.
55 *Next Generation Science Standards*, pp. 126-27.

to use properly. They neither instruct students how to create a rigorous model nor how to subject a model to a rigorous critique.[56] Most broadly, the NGSS's excessive emphasis on models rather than empirical data encourages students to confuse the map for the territory, the abstracted representation provided by a model for the natural world itself.[57]

56 And see *Framework*, pp. 64-67.
57 "Map-territory relation," Wikipedia, https://en.wikipedia.org/wiki/Map–territory_relation.

The Detrimental Consequences of the NGSS

The Detrimental Consequences of the NGSS

Political Indoctrination

The NGSS's entire climate sequence is heavily politicized, with an emphasis on activism to reduce pollution, etc., rather than disinterested inquiry into the nature of climate science.[58] From kindergarten onward, the NGSS insert environmentalist policy prescriptions and label them as science. The doctrines of sustainability and human-caused climate change are replete in the NGSS. In fact, they are so conspicuous that it would be impossible for even a neutral reader to miss. This hails back to the United Nations' *Agenda 21*[59] document, signed by President George H.W. Bush, and President Bill Clinton's Council on Sustainable Development document titled *Towards a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century.*[60] These two documents avow to restructure education to indoctrinate unsuspecting schoolchildren, and ultimately society as a whole, with principles of sustainable development and climate change. It can be no coincidence or surprise that the NGSS are rife with politically charged dogma, and to guarantee that this dogma is sealed in the minds of schoolchildren, the NGSS are written in a format that elevates their underlying assumptions to the level of empirically tested evidence.

58 And see Gross, "Final Evaluation," p. 48.

59 "United Nations Sustainable Development: Conference on Environment and Development: AGENDA 21," https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf.

60 President's Council on Sustainable Development, "Towards a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century," https://clintonwhitehouse2.archives.gov/PCSD/Publications/tsa.pdf.

Examples of political indoctrination embedded in a standard:

Example #1

> MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

> [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as the air, water, or land).][61]

Notice the words "human impacts," "human environmental impacts," and "pollution" in this standard and the accompanying clarification statements. The implication is that humans can only impact the earth negatively, reinforcing the political doctrine of "sustainability."

Example #2

> MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.[62]

Note the underlying assumptions that (1) global warming has occurred over the past century and (2) there is accurate and reliable

61 *Next Generation Science Standards*, p. 83.
62 Ibid.

evidence of this. Whether global warming has occurred over the past century is not even presented. Students are asked simply to "clarify" the evidence, leading them to accept that global warming is a verified fact based on trustworthy data ("evidence").

> Example of political indoctrination embedded in clarification statement:

> HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

> [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruptions, ocean circulation; 10s-100s of years: changes in human activity, ocean circulation, solar output; 10s-100s of thousands of years: changes to Earth orbit and the orientation of its axis; and 10s-100s of millions of years: long-term changes in atmospheric composition.][63]

The standard correctly connects variations in the flow of energy to climate change, but the clarification statement actually obscures the standard it is supposed to clarify. The clarification classifies the causes of climate change by timescale rather than by the amount of energy they release—when the amount of energy each cause releases should be the central concern of a model associating energy variations to climate variation, and the timescale a secondary concern. The clarification also elides the distinction between anthropogenic emissions of carbon dioxide--a key component of global warming theories—and anthropogenic energy release. The sequencing by increasing timescale is certainly incoherent, and strongly suggests an attempt, fitting neatly into the alarmist theory of climate change, to present the timescale of human

63 Ibid., p. 122.

activity as the quantity of human-released energy. If this is not deliberate propaganda, it is a clarification statement written with astonishing incompetence.

Human "impacts" described in the NGSS are overwhelmingly negative: "Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; and how the loss of wetlands causes a decrease in local humidity that further reduces the wetlands' extent."[64] The NGSS never even consider (for example) that intensive agricultural monoculture, since more productive, can reduce pressures on wilderness habitat, or that the use of fossil fuels can inhibit deforestation by reducing firewood use. Climate warming is assumed rather than argued—and the NGSS skim over the complex science behind that arguable conclusion.[65] Discussions of renewable energy[66] fail to mention scientific concepts such as power density and Betz's Law that highlight the difficulty of transitioning to renewable energy—surely material for an educational science class.[67] Neither do the NGSS mention how and to what extent negative feedback loops stabilize the climate.

What's more, the NGSS do not acknowledge, in their endless nostrums on "biodiversity," that the vast flourishing of humanity, and its growth to nearly eight billion people, depends upon the prior flourishing of agricultural monoculture—and the NGSS include statements which have no value in a science education, such as "Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value."[68] Nor is there ever a sense that human flourishing—human

64 Ibid., p. 122; and see p. 126.
65 Ibid., p. 83.
66 Ibid., pp. 41, 83-84, 97.
67 Robert Bryce, "The Real Problem with Renewables," *Forbes*, May 11, 2010, https://www.forbes.com/2010/05/11/renewables-energy-oil-economy-opinions-contributors-robert-bryce.html#6ba2abc51403; Betz's Law, Wikipedia, https://en.wikipedia.org/wiki/Betz%27s_law.
68 *Next Generation Science Standards*, p. 116.

needs and human desires—is a greater good than biodiversity, etc. The NGSS instead import the unscientific terms *social* and *sustainability*:

> All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. ... The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources."[69]

These terms smuggle social justice activism into America's science classes.

Soft "Science" vs. Hard Science

Reading the entire NGSS document confirms suspicions that national standards are merely the latest pipe dream of the "Education Industrial Complex." This becomes remarkably clear when we evaluate the NGSS in terms of the influence of "social" (soft) science. Apparently, quantitative analysis is too limiting or restrictive, while impressions, opinions, and ever-present "feelings" are much more "human" and "social."

Conducting genuine hard science requires skills, discipline, and an appropriate balance of both quantitative and qualitative methods. Unfortunately, the NGSS miss numerous quantitative learning opportunities with some 26 directives favoring qualitative analysis over quantitative. These do not effectively provide students with numeric concepts and tools, particularly in the younger grades where math familiarity and competence are critical for future success.

69 Ibid., p. 126.

Examples of qualitative analysis favored over quantitative analysis:

Example #1

> 1-ESS1-2. Make observations at different times of the year to relate the amount of daylight to the time of year.
>
> [Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.]
>
> [Assessment Boundary: Assessment is **limited to relative amounts of daylight, not quantifying the hours or time of daylight**][70] [Emphasis added.]

Which is more useful to a student—"I think/feel that days are shorter in the winter"—or determining the length of seasonal daylight/darkness and incorporating sunrise/sunset data as evidence? This is a lost opportunity to teach students to collect quantitative data.

Example #2

> 2-ESS2-2. Develop a model to represent the shapes and kinds of land and bodies of water in an area.
>
> [Assessment Boundary: Assessment **does not include quantitative scaling in models.**][71] [Emphasis added.]

This is a missed opportunity to measure landforms, incorporate map reading, introduce Google Earth, etc.—useful and enjoyable activities for 2nd graders.

70 Ibid., p. 14.
71 Ibid., p. 21.

Example #3

> 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

> [Assessment Boundary: Assessment **does not include quantitative measures** of changes in the speed of an object **or on any precise or quantitative definition** of energy.][72]

Differences are important. Measurement, data, and the resulting information, not opinion, must be used to determine and understand those differences.

The Problems of Integrated Sciences in High School

The NGSS at all grade levels are "integrated," meaning that the subject headings (called "disciplinary core ideas") are grouped into four domains: physical sciences, life sciences, engineering, and earth and space sciences. These domains are then expected to be taught *in each grade level*.

In grades K-8 this is not problematic, but at the high-school level it creates some challenges. For the state that requires three years (units) of science for graduation, it is easy to specify what exactly constitutes a one-year course in the traditional format. Ordinarily, stand-alone courses in physical science, biology, and chemistry or physics (or courses approved as suitable substitutions) are offered. However, with engineering and earth and space sciences added, physical science severely reduced, and chemistry and physics removed, the traditional stand-alone courses do not exist within the NGSS. Instead, each of the domains is taught within each academic year. The result is that each domain will

72 Ibid., p. 35.

be given short shrift compared to the full year devoted to it under the traditional method.

Consider how this would work. Unless a high-school science teacher is qualified to teach across all domains (e.g., a biology teacher also teaching earth and space science), the most practical solution would be to have teachers "team teach" the content—an expensive, inefficient, and difficult-to-schedule use of staff time—or to have science teachers devote themselves to domains where they have no expertise. A biology teacher, for example, would probably teach a nine-week block of 9th-grade life science, then a nine-week block of 10th-grade life science, and again a nine-week block of 11th-grade life science. Unless students are required to complete a fourth year of science for graduation, they only need to sit for three nine-week blocks, which is one-quarter less life science instruction than offered in the traditional high-school biology course.

Even if it is possible for the four traditional domains to be condensed into three years, which would ensure that all the high-school standards are covered, the depth of instruction is then questionable. Scheduling issues, when trying to ensure that one teacher can teach across grade levels, would present some feasibility challenges for schools and districts, especially those where the upper grades may be housed in different locations. One gets the impression that the creators of the NGSS have no practical experience in running a school.

The NGSS make it difficult-to-impossible for a school to fulfill state science education requirements. They also fit very badly with science teachers' training, which is generally to specialize in particular subject areas. The NGSS make it virtually impossible for a real-world science department to meet its obligations to the state, to its teachers, to its students, and to taxpayers.[73]

73 Sydney Johnson, "How one high school's dispute reflects the struggle to teach California's science standards," *EdSource*, October 18, 2019, https://edsource.org/2019/how-one-high-schools-dispute-reflects-the-struggle-to-teach-californias-science-standards/618752.

Unbalanced Content

One of the hot-button issues in public school science instruction is, of course, how it handles the topic of evolution. While taught in science courses throughout the nation, evolution is given a much more prominent place in the NGSS. Furthermore, the NGSS present all steps in the evolutionary process as irrefutable, factual knowledge with overwhelming empirical evidence rather than a theory with strong supporting but not conclusive evidence.

The disinterested pursuit of truth through reliable processes and methods—now missing in the NGSS—is absolutely essential in the scientific disciplines. Guiding a student through multiple theories, each with some confirming and some disconfirming evidence, will lead to a better understanding of the process of inquiry and reasoning in science. This is not a new argument, but it is one that bears repeating.

Perhaps a greater concern is the disproportionate amount of attention given to evolution in the NGSS. This topic constitutes 26 percent of the grade K-8 life science standards (Figure 1) and 28 percent of the grade 9-12 life science standards (Figure 2), calculated by the number of standards dedicated to this content. It is neither necessary nor reasonable to devote so much time to this one subject at the expense of more essential science content, such as the human body, electrical systems, or chemistry. This is yet another example of the NGSS's unbalanced priorities.

Additionally, the fact that the aspects of the biology curriculum most obnoxious to fundamentalist Christians[74] have been emphasized so strongly smacks more of a culture war than of an impartial devotion to science education. There is no direct textual proof of this in the NGSS standards—but neither is there a better explanation for why genetics should be immune to their general razoring of content knowledge, sacrificed so indiscriminately to the demands of *process* and *diversity*.

74 *Next Generation Science Standards*, Appendixes, p. 8.

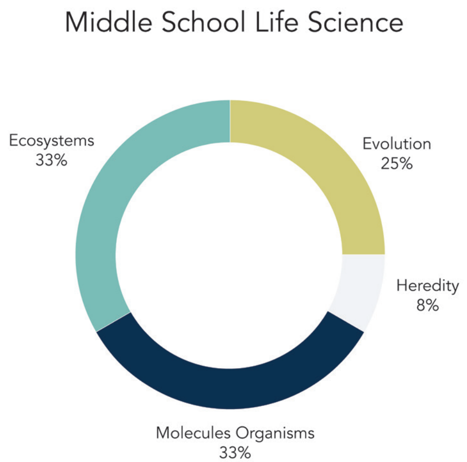


Figure 1

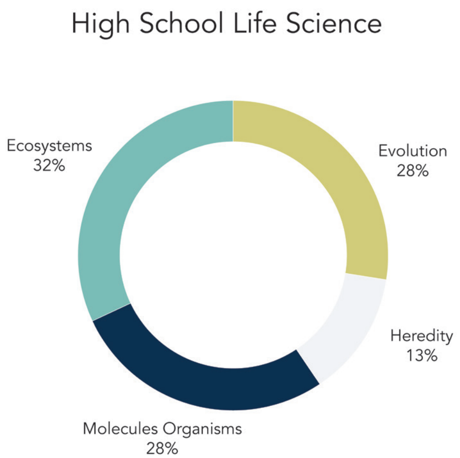


Figure 2

The Empty Promise: The NGSS as STEM Preparation

There has been a great deal of discussion in academic and workforce-planning circles regarding the need for K-12 science, technology, engineering, and mathematics (STEM) preparation for college-bound students. The NGSS will only steepen the decades-long slope of failure mentioned in *A Nation at Risk*[75] because they neglect the critical basics of STEM, thereby providing no substantial foundation for advanced work.

The NGSS Introduction clearly states, “The NGSS content is focused on preparing students for college and careers.”[76] Likewise, the Introduction section of the same document clearly states:

> Implementing the NGSS will better prepare high school graduates for the rigors of college and careers. In turn, employers will not only be able to hire workers with strong science-based skills in specific content areas, but also with skills such as critical thinking and inquiry-based problem solving.[77]

But this very same document later states:

> The NGSS do not define advanced work in the sciences. Based on reviews from college and career faculty and staff, the NGSS **form a foundation** for advanced work, **but students wishing to move into STEM fields should be encouraged to follow their interest with additional coursework.**[78] [Emphases added.]

These contradictory statements reveal the deceptively flawed nature of the NGSS. The buzzwords “college- and career-ready” are marketing tools embraced by supporters, but a search for basic STEM vocabulary reveals an appalling lack of foundational terminology and

75 “A Nation at Risk.” National Commission on Excellence in Education, https://www2.ed.gov/pubs/NatAtRisk/risk.html.

76 *Next Generation Science Standards*, p. xiii.

77 Ibid., p. xv.

78 Ibid., p. xvii.

associated concepts. How can anything be discussed if we don't have a word with which to identify it?

Students are entitled to expect that these new standards will prepare them for college-level coursework, but the NGSS apparently want them to read the fine print and pursue advanced high-school courses in addition to their own standards. Whether high-school students will recognize the deficiencies in their own science education is a genuine concern. Students—and their parents—should be able to depend on their primary and secondary education to give them the prerequisite knowledge and skills to succeed in their college major.

Pedagogical Differences: Performance vs. Content Standards

Pedagogical Differences: Performance vs. Content Standards

Skills vs. Knowledge

The NGSS are written as performance standards ("what can you do?") rather than content standards ("what do you know?"). A good standard should clearly convey both the essential knowledge to be learned *and* the necessary practices. The NGSS sacrifice content for performance, with project learning being central to the science classroom. Hands-on projects are important and make learning enjoyable, but a disproportionate focus on project learning results in a haphazard teaching and learning process. Disregard for the importance of building an adequate knowledge base and sufficient memory ("scaffolding") before hands-on practices results in a flyswatter approach to science education that is somewhat fragmented at best and completely disorganized at worst.

Humans have a natural desire to know and to understand, as Aristotle posits in the opening line of his *Metaphysics;* we therefore need to examine the way in which the NGSS are designed for learning. The entire NGSS document is written as inquiry-based standards (a.k.a. "problem-based learning," "experiential learning," "discovery learning," and "constructivist learning"). They are constructivist in design, meaning that learners construct their own solutions to the problems presented. The underlying assumption of this heuristic process is that the learner can best acquire new knowledge by experiencing the problem-solving process.[79] Furthermore, there is an assumption that knowledge can be acquired through the same processes as those who practice the discipline being studied.[80] We challenge these assumptions.

79 Paul A. Kirschner, John Sweller and Richard E. Clark, "Why Minimal Guidance during Instruction does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching," *Educational Psychologist* 41, no. 2 (2006), 75-86.

80 Paul A. Kirschner, "Epistemology, Practical Work, and Academic Skills in Science Education," *Science and*

Every pedagogical school accuses its rivals of monomania and of failing to maintain the proper balance of instructional elements such as content knowledge and process knowledge. Nevertheless, the NGSS's disdain for pedagogy that emphasizes prompts such as *describe, identify, recall, define, state,* and *recognize* strongly suggests that students educated with NGSS standards will have little ability to engage in any of these activities—and will thus be poorly equipped at best to complete undergraduate-level science coursework.[81] Likewise, the NGSS's condemnation of the Kansas 2007 Science Education Standards for emphasizing *understanding* rather than *prediction* and *application* suggests NGSS-educated students will be unlikely to graduate with more than the vaguest understanding of science content.[82]

The NGSS's proud affirmation that "After a college- and career-readiness review, some content was removed" exemplifies how they cripple students' readiness for college or career.[83]

The New Strategy: Just "Look it Up"

Many educators appear to have dismissed the importance of explicitly teaching content. This was evidenced by the open opposition to it by one state department of education in a state legislative K-12 Joint Education Subcommittee hearing on the NGSS in March 2016. One of the authors of this report testified to the subcommittee, expressing concerns about the lack of content standards in the NGSS. The response by the Department of Education's science education representative was, "We don't teach content anymore; that is the old way. If kids want to know something, they can just Google it." Sadly, this is a common view held by educators: that children need not commit information to long-term memory because it is now at their fingertips via the internet. This

Education 1, no. 3 (1992), 273-299.

81 *Next Generation Science Standards*, Appendixes, p. 18.

82 Ibid., p. 19.

83 Ibid., p. 5.

perspective raises two questions: (1) Do students really learn best, or at all, from constantly looking up information only at the moment when they need it, and (2) if information on a particular subject is not learned and stored in long-term memory, how can a student (or anyone, for that matter) discern whether he finds accurate information online? We need some degree of stored knowledge in order to evaluate the information found in learning resources. Textbooks, whether printed or online, undergo professional review for accuracy. Not so with just any web site.

Without an expectation that students will learn, store, and master important content, two further questions emerge regarding the NGSS. Is it possible to (1) objectively and accurately evaluate a student's progress (*i.e.,* issue a grade), and (2) evaluate the student's readiness to move on to a higher level of science reasoning? In fact, one must wonder if NGSS-educated students will even learn correct science vocabulary. Terminology and vocabulary are important. They allow us to communicate effectively. They cannot be the focus of scientific teaching and learning, but they have immense value.

In the NGSS classroom, the teacher is merely the "guide on the side" while students work on projects for days or weeks at a time. Implementation of the NGSS is thus a way to codify project learning in place of traditional science-education pedagogy.

Lack of College Preparation

Proponents of the NGSS assume that the standards' missing content will be taught at the collegiate level and is therefore unnecessary for high-school students to learn. This is a manifestly bankrupt assumption.

First, repetition is beneficial, indeed critical, in education at all levels. As we add knowledge to memory, we are able to add more depth and breadth to existing knowledge when academic content is revisited in the K-12 years. This is the reason Disciplinary Core Ideas are repeated in K-5, middle school, and high school in the NGSS. Omitting massive amounts of traditional high school science content with the claim that it will be learned later in college is educational malpractice. Providing high school students with at least a basic understanding of science concepts will establish the foundation for more complex material at the collegiate level and beyond. Moreover, college professors should not be expected to teach high-school level science content to fill in the gaps, nor do they have the class time to continually review basic concepts. If they are forced to do so, the course would be remedial, which proponents of Common Core and the NGSS claim they are trying to prevent. Furthermore, students who choose not to attend college after high school would not be exposed to fundamental science concepts, the understanding of which their parents and grandparents took for granted.

An Education Experiment

An Education Experiment

The Absence of Pilot Testing

The NGSS were never pilot tested prior to adoption. This is strikingly reminiscent of the Common Core fiasco, where states adopted standards with no evidence of quality, no pilot test, and little to no process in place for teachers' professional development at the time of implementation. Once again, American school children are subjects of an inescapable education experiment across the nation, the results of which will be unknown until an entire generation of kids have been taught—or not—using science standards that may be subpar.

Curiously, the absence of any pilot testing of the NGSS didn't seem to concern entities that generate K-12 science instructional research. In 2013, the Museum of Natural History collaborated with the K-12 Alliance at WestEd and Biological Sciences Curriculum Study (BSCS) on a two-year project to design and field test NGSS instructional materials, professional development for science teachers, and leadership instruction for science mentors and advisors, with the intent to take the professional development process to science teachers in the classroom.[84] WestEd is an educational research and development non-profit group. The BSCS is another non-profit educational organization that does exactly what its name says: curriculum study in the area of biological science. Both organizations' stated aim is to produce science education research and utilize the findings to improve education quality.

The goal of this collaborative project, undertaken from October 2013 to September 2015, was to take the new NGSS instructional tools to educators and teach them how to utilize those tools in their classrooms. This makes sense for a new set of education standards; however, it is troubling that this was a design and field-test project started *after* the

84 "Moving Standards into Practice: Five Tools and Processes for Translating the NGSS for Instruction and Classroom Assessment," American Museum of Natural History, 2019, http://cosss.org/resources/Documents/Denver/JimShort_AMNH_GNSS_Tools.pdf.

publication of the NGSS and their subsequent adoption by several states, the first being Rhode Island, which adopted the NGSS in May 2013. More states adopted the standards later that year. Field tests should be completed *prior to* widespread adoption, not afterward.

SCIENCE, TECHNOLOGY, AND SOCIETY

The NGSS's inclusion of "Science, Technology, and Society" (STS)[85] incorporates a field whose disciplinary assumptions are that power and politics constitute science:

> The political concerns of STS have pivoted around the formulation and criticism of liberalism. Liberal values of individualism, instrumentalism, meliorism, universalism, and conceptions of accountability and legitimacy have been closely related to understandings of scientific rationality, empiricism, and scientific and technological progress.[86]

A typical STS undergraduate program dedicates itself to considering "How should societies manage those fields [of science and technology] to achieve just and sustainable communities?"[87] The NGSS's dependence on STS pedagogy is a dependence on pedagogy devoted to progressive advocacy and criticism of everything that makes science possible—individualism, scientific rationality, empiricism, and scientific and technological progress.

STS is fundamentally antithetical to science education: science's distinctive virtue is its ambition, and astonishing success, at making

85 *Next Generation Science Standards*, Appendixes, pp. 108-12.

86 Radhika Gorur, et al., "Politics by other means? STS and research in education," *Discourse: Studies in the Cultural Politics of Education* 40, 1 (2019), https://www.tandfonline.com/doi/full/10.1080/01596306.2018.1549700.

87 The Science, Technology & Society Major, University of Washington Bothell, https://www.uwb.edu/science-technology-society.

claims of universal knowledge, knowledge for which power and politics are by definition irrelevant. STS's basic assumptions cannot be reconciled with the aspirations and true nature of science. Moreover, the NGSS's STS-inspired focus on the social framework of science necessarily comes at the expense of classroom hours which ought to be devoted to content knowledge.

In detail, the NGSS's dependence on STS explains its odd emphasis on how to *restrict* the use of science and technology: "people make decisions for social and environmental reasons that ultimately guide the work of scientists and engineers ... [*Framework*] emphasizes the limits to growth imposed by human society and by the environment, which has limited supplies of certain non-renewable resources."[88] The NGSS's emphasis on science content that informs subjects such as health care and the natural environment also derives from the STS focus on progressive advocacy.[89] STS pedagogy also underwrites the NGSS's focus on *diversity* and "communities."[90]

The NGSS's dependence on STS also helps explain the bizarre interpolation of 'communal validation' into the assessment of scientific truth: "A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted."[91] The stipulation of approval from the "science community" as a requirement for "acceptance" presumably is meant to underwrite climate change activism, which loudly proclaims the authority of a spurious "consensus."[92] But it also tends to diminish the value of lone dissenters who challenge and overturn false beliefs endorsed by scientific consensus—Luis and Walter Alvarez boldly and correctly proposing that an asteroid impact

88 *Next Generation Science Standards*, Appendixes, p. 109.
89 Ibid.
90 Ibid.
91 *Next Generation Science Standards*, p. 121.
92 Joseph Bast and Roy Spencer, "The Myth of the Climate Change '97%'," *The Wall Street Journal*, May 26, 2014, https://www.wsj.com/articles/joseph-bast-and-roy-spencer-the-myth-of-the-climate-change-97-1401145980.

did a great deal to kill off the dinosaurs, John Yudkin's valiant persistence in pointing out the deleterious health effects of sugar, Alfred Wegener's widely derided but correct formulation of the theory of continental drift.

The NGSS's reliance on STS promotes conformity to scientific consensus rather than independent, stubborn dedication to scientific truth. STS's dismal focus is on creating scientists perfectly equipped to function as smooth-talking, collaborative bureaucrats—Lysenkos to impose ideology rather than Sakharovs to stand up as lone voices for the truth.

Diversity and Equity

Diversity and Equity

Introduction

The deepest damage to the NGSS derives from their commitment to *diversity and equity*—throughout, but made explicit in Appendix D: "All Standards, All Students": Making the Next Generation Science Standards Accessible to All Students.[93] This commitment provides an incredible tangle of euphemisms to obscure what these terms mean, although the radical core occasionally emerges: "Equity as an expression of social justice is manifested in calls to remedy the injustices visited on entire groups of American society."[94] The central claim is that *non-dominant groups*, such as blacks, Hispanics, the poor, and girls, don't do so well in science classes—because of the "privilege" of "dominant groups." "While the student population in the United States is becoming more diverse, science achievement gaps persist by demographic subgroups."[95] Science standards therefore must be framed so that "Achievement gaps [are] closed among demographic subgroups of students."[96] The NGSS characterize the "achievement gap" as a function of privilege, which the standards must strive to eliminate.[97] *Framework* informs the reader that the standards were crafted in their entirety with *diversity* in mind: "In designing standards and performance expectations, issues related to diversity and equity need to be taken into account. In particular, performance expectations should provide students with multiple ways of demonstrating competence in science."[98]

The NGSS claim that a focus on closing "achievement gaps" can be harmonized with "improved science outcomes … for all students."[99] Yet

93 *Next Generation Science Standards*, Appendixes, pp. 25-39; and see *Framework*, pp. 28-29, 277-95)
94 *Framework*, p. 278.
95 *Next Generation Science Standards*, Appendixes, p. 36.
96 Ibid.
97 Ibid., pp. 25-26.
98 *Framework*, p. 307.
99 *Next Generation Science Standards*, Appendixes, p. 36.

the NGSS's revealed preference is to eliminate the "achievement gap" by removing all difficult material that produces said "gap." The NGSS reduced the rigor of their standards so that everyone could pass them—even if that meant getting rid of science content sufficient to actually prepare *any* student for undergraduate science classes. The NGSS thereby drastically worsened science outcomes for all students.

> All standards are expected of all students. Though this is a foundational commitment of the *Framework* and is discussed at length in Appendix D of the NGSS, it bears repeating here because of its implications for course design. This approach is much more than just a way to refute the common notion that learning physics is only for students in advanced math, or that taking earth and space sciences is only for students who are not on the college track. All standards, all students.[100]

The NGSS's coercively egalitarian commitments preclude allowing any students to escape its misguided limitations on science instruction.

The NGSS's commitment to *diversity and equity* produce several distinct deleterious consequences.

Reduced Content Knowledge

The NGSS do not explicitly say "we have removed rigorous content because we don't believe black and Hispanic students can handle it." Yet the material they substitute for content knowledge, such as process and inquiry, is material meant in various ways to inspire and/or support "non-dominant populations."[101] Because *diversity* is of greater importance than content knowledge, adherence to the NGSS will almost

100 Ibid., p. 114.
101 Ibid., p. 8.

certainly sacrifice content knowledge whenever *diversity* demands classroom time. Such sacrificed content knowledge includes "intermediate knowledge and instructional steps."[102] The NGSS evince faith that implicit content knowledge will be taught, though it has no faith that process knowledge can be conveyed implicitly.[103]

The NGSS's reduction of content knowledge, pursued so as to ensure sufficient curricular room for *diversity and equity*, succeeds only by making all students equally unready to pursue science.

Cant

The cant of diversity also affects the content of the NGSS. A lesson on biological growth and development ritually intones that "Plants and animals have unique and diverse life cycles."[104] This is a scientific tautology whose phraseology echoes the progressive vocabulary of virtue and positively impedes instruction of the more important scientific insights into uniformity and similarity across species. The failure of the NGSS to mention the word *taxonomy*, classification on the basis of shared characteristics, presumably owes in some measure to the standards' obeisance to the cant of diversity.

Substituting Process Knowledge

The NGSS consistently substitute process knowledge for content knowledge. They do so largely to aid "non-dominant groups" who cannot be assumed otherwise to possess an interest or capacity in science.

> A growing body of evidence suggests that student engagement in practices helps reduce achievement gaps …

102 Ibid., p. 8.
103 Ibid., pp. 8, 11-12.
104 *Next Generation Science Standards*, p. 27.

> Specifically, one study found no significant difference in performance between subgroups (gender, ethnicity, or economically disadvantaged) when inquiry was used in instruction, as opposed to traditional classroom instruction where a significant achievement gap between subgroups of students was found ... In addition, Lee and colleagues (2006) found that while student achievement increased overall with inquiry-focused instruction, students from non-mainstreamed or less privileged backgrounds showed much higher gains than their main-streamed, more privileged counterparts.[105]

> Crosscutting concepts offers [*sic*] frameworks to conceptualize disciplinary core ideas. In this way, students think of science learning not as memorization of isolated or disconnected facts, but as integrated and interrelated concepts. This is a fundamental understanding of science that is often implied as background knowledge for students in "gifted," "honors," or "advanced" programs. Through the NGSS, explicit teaching of crosscutting concepts enables less privileged students, most from non-dominant groups, to make connections among big ideas that cut across science disciplines. This could result in leveling the playing field for students who otherwise might not have exposure to such opportunities.[106]

Gross found the NGSS's focus on process knowledge to have a strongly inimical effect on the standards.[107] It is worth emphasizing that this focus proceeds at least partly from the NGSS's desire to promote *diversity and equity* as much as from misguided pedagogical theory.

105 *Next Generation Science Standards*, Appendixes, p. 16.
106 Ibid., p. 30.
107 Gross, "Final Evaluation," pp. 19-21.

Substituting Communication Skills

The NGSS dedicate substantial classroom time to developing "communication skills."[108] The NGSS predicate this focus on the *Framework*'s perfectly true statement that scientists and engineers need to communicate effectively.[109] Yet the standards' actual communication focus is on supporting remedial literacy and numeracy for "non-dominant populations."

> For example, students are expected to engage in argumentation from evidence; construct explanations; obtain, synthesize, evaluate, and communicate information; and build a knowledge base through content-rich texts across the three subject areas. Such convergence is particularly beneficial for students from non-dominant groups who are pressed for instructional time to develop literacy and numeracy at the cost of other subjects, including science.[110]

The NGSS's vaunted synergy with the Common Core State Standards is actually a synergy of science instruction with CCSS tests in basic English and mathematics, and the NGSS remind teachers that science instruction should not go too quickly: "As is the case with the mathematics standards, the NGSS should always be interpreted and implemented in such a way that they do not outpace or misalign to the grade-by-grade standards in the CCSS for literacy."[111] The NGSS's desire to promote *diversity and equity* subordinates science instruction to remedial English and mathematics.

108 E.g., *Next Generation Science Standards*, p. 96.
109 *Framework*, p. 53.
110 *Next Generation Science Standards*, Appendixes, p. 27; and see 29, 50.
111 *Next Generation Science Standards*, Appendixes, pp. 34, 159; and see *Framework*, pp. 297, 306.

Substituting Identity Politics Science Heroes

The NGSS also apportion significant classroom time to informing students that members of "non-dominant groups" have acted as scientists, since they will presumably otherwise lose interest in science.

> At that time, although the goal of *Science for All Americans* was visionary, the definition of science in terms of Western science while ignoring historical contributions from other cultures presented a limited or distorted view of science. The NGSS, by emphasizing engineering, recognize the contributions of other cultures historically. … **Girls.** The research literature points to three main areas where schools can positively impact girls' achievement, confidence, and affinity with science and engineering: … (2) curricula to improve girls' achievement and confidence in science by promoting images of successful females in science.[112]

The NGSS's own catalogue of scientific topics worthy of extended study indicates how difficult it is to find significant episodes in the history of science that don't depend on the work of "dominant populations."

- Copernican Revolution
- Newtonian Mechanics
- Lyell's Study of Patterns of Rocks and Fossils
- Progression from Continental Drift to Plate Tectonics
- Lavoisier–Dalton and Atomic Structure
- Darwin's Theory of Biological Evolution and the Modern Synthesis
- Pasteur and the Germ Theory of Disease
- Watson and Crick and the Molecular Model of Genetics[113]

112 *Next Generation Science Standards*, Appendixes, pp. 29, 31; and see *Framework*, p. 288.
113 *Next Generation Science Standards*, Appendixes, p. 101.

In the pursuit of inspirational figures for *diversity and equity*, the NGSS will logically need to eradicate these inspirational and educational topics from the history of science, which are central to that which science students must learn in an adequate sequence of K-12 science classes.

Focus on "Communities"

The NGSS believe that the best or only way to serve "non-dominant groups" is to select science that also doubles as education embedded within the "communities" of these "non-dominant groups."

> **Economically disadvantaged students.** Strategies to support economically disadvantaged students include (1) connecting science education to students' sense of "place" as physical, historical, and sociocultural dimensions; (2) applying students' funds of knowledge and cultural practices; (3) using project-based science learning as a form of connected science; and (4) providing school resources and funding for science instruction. ... **Students from major racial and ethnic groups.** Effective strategies for students from major racial and ethnic groups fall into the following categories: (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems, including role models and mentors of similar racial or ethnic backgrounds.[114]

This focus on "communities" goes far in explaining the NGSS's emphasis on project-based inquiry, science assignments in "informal environments" outside the classroom, engineering, and climate science, all

114 Ibid., pp. 31-32.

of which are intended to promote community involvement, hence interest in science, by students in "non-dominant groups."[115] For example,

> The NGSS inclusion of engineering with science has major implications for non-dominant student groups. From a pedagogical perspective, the focus on engineering is inclusive of students who may have traditionally been marginalized in the science classroom or experienced science as not being relevant to their lives or future. By asking questions and solving meaningful problems through engineering in local contexts (e.g., watershed planning, medical equipment, instruments for communication for the deaf), diverse students deepen their science knowledge, come to view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways.[116]

The "community" focus also introduces further concepts that will seriously degrade science instruction. The idea that "Students bring to the science classroom 'funds of knowledge' that can serve as resources for academic learning," a meretricious notion imported from the education schools,[117] further reduces the NGSS's focus on the core of science instruction, the body of professional knowledge that no lay community can impart and that justifies the very existence of a credentialed body of science teachers who have received lengthy instruction into the nature of that professional knowledge.[118] When *Framework* states that "All science learning can be understood as a cultural accomplishment," it fails to provide the proper corollary, that proper pedagogy should focus on inculcating students with the norms and practices of the professional

115 Ibid., pp. 31-32, 109.

116 Ibid., p. 104.

117 Carlos G. Vélez-Ibáñez and James B. Greenberg, "Formation and Transformation of Funds of Knowledge among U.S.-Mexican Households," *Anthropology & Education Quarterly* 23, 4: 313-35, https://www.jstor.org/stable/3195869?seq=1.

118 *Next Generation Science Standards*, Appendixes, p. 109.

culture of science as the indispensable priority, not on "allowing science and science understanding to grow out of lived experiences."[119]

The focus on "communities" also subserves identity-group politics, not least by assuming that membership in an identity-group is the most salient student characteristic, and "social activism"—which we will treat separately below.[120] The focus on "communities" appears designed to insert at best marginally useful science instruction whose main purpose is to forward progressive political advocacy.

We may note here a basic tension in the NGSS's assumptions. On the one hand, they take the tacit ability to integrate and interrelate science concepts as "a fundamental understanding of science that is often implied as background knowledge for students in 'gifted,' 'honors,' or 'advanced' programs."[121] On the other hand, they wish science instruction to rely heavily on "non-dominant" communities[122] whose members apparently lack a fund of the knowledge most relevant for actual success in science: how to integrate and interrelate science concepts. The NGSS's own premises would indicate that they ought instead to focus on explicit classroom instruction in integrative and interrelative conceptualization, and that reliance on "community" funds of knowledge will impose a particular and substantial opportunity cost on students from "non-dominant groups"—perhaps generally, but certainly in science education.

We may also note that the lightly inserted phrase "role models and mentors of similar racial or ethnic backgrounds"[123] will easily serve as a justification for race preferences, to reserve science teaching positions for members of "non-dominant groups." The NGSS's focus on *diversity and equity* thus casually supports race discrimination in hiring as well as substantial distortions in pedagogy.

119 *Framework*, pp. 283-84.
120 *Next Generation Science Standards*, Appendixes, pp. 31-32.
121 Ibid., p. 30.
122 Ibid., p. 32.
123 Ibid., p. 31.

Activism

The NGSS devote an astonishing amount of time to "activism"—astonishing not least because the proper amount of "activism" in science education is "zero." The NGSS suggest their activist orientation early on with the peculiar formulation that "by integrating technology and engineering into the science curriculum, teachers can empower their students to use what they learn in their everyday lives"—*empower* in *everyday lives* is now a familiar phraseology from activist pedagogy.[124] The NGSS follow up this implicit endorsement of activism with (as noted above) the explicit call that science education include "social activism."[125]

Thus we have what appears to be a coded call to fuse public school education with an environmentalist non-governmental organization: "For example, a teacher could tap into the community as a resource by recruiting a community member(s) to assist an upper elementary class, as students investigate the pollution along a river near the school."[126] The NGSS also provide room for identity-group activists to insert themselves into crafting science education: "Members of diverse cultural groups can play a critical role in the development and implementation of programs, serving as designers, advisers, front-line educators, and evaluators of such efforts."[127] More generally,

> Finally, "place-based" science education is consistent with culturally relevant pedagogy … Through social activism, students develop critical consciousness of social inequities, especially as such inequities exist in their communities. When youth find science education to be empowering and transformative, they are likely to embrace and further investigate what they are learning, instead of being resistant

124 Ibid., p. 3.
125 Ibid., p. 31.
126 Ibid., p. 33.
127 Ibid.

> to learning science. Thus, school science should be reconceptualized to give a more central role to students' lived experiences and identities.[128]

Contemporary education literature outlines explicit objectives for science educators: social justice, sociopolitical development, and political engagement, especially in the field of environmental education.[129] Kornbluh and colleagues explain how the NGSS can be used as groundwork for training students to conduct research in the interest of "social justice," known as Youth Participatory Action Research (YPAR).[130] Justice-centered science pedagogy uses science education as the impetus for social change, rather than for the disinterested pursuit of science knowledge. Morales-Doyle stated this clearly in his article on justice-centered pedagogy: "YPAR challenges the notions of objectivity and expertise that have been central to Western science. It also rejects knowledge generation for the purposes of dominating nature or even for its own sake. Instead, it reframes the goal of understanding the world as part of creating more just and sustainable social conditions."[131] It seems clear from this statement that the contributions and methods of Western science have indeed been dismissed.

In other words, the NGSS facilitate the work of those activists who steer science education toward training progressive activists.

Dedicating School Resources

The NGSS call for a massive diversion of school resources to support "non-dominant students," under the rationale that this is purely a matter of science pedagogy.

128 Ibid.

129 Alexandra Dimick, "Student Empowerment in an Environmental Science Classroom: Toward a Framework for Social Justice Science Education," *Science Education* 96, no. 6 (2012), 990-1012.

130 M. Kornbluh et al., "Youth Participatory Action Research as an Approach to Sociopolitical Development and the New Academic Standards: Considerations for Educators," *Urban Review* 47, no. 5 (2015), 868-892.

131 Daniel Morales-Doyle, "Justice-Centered Science Pedagogy: A Catalyst for Academic Achievement and Social Transformation," *Science Education* 101, no. 6 (2017), 1034-1060, esp. p. 1038.

> School resources are likely to have a greater impact on the learning opportunities of non-dominant student groups. This is because the dominant student group is more likely to have the benefits of other supports for their learning, such as better-equipped schools, more material resources at home, and highly educated parents. In contrast, the academic success of non-dominant students depends more heavily on the quality of their school environment; yet, it is these students who are less likely to have access to high-quality learning environments. Thus, inequitable resources are a central concern. The NGSS present both opportunities and challenges to reconceptualize the allocation and utilization of school resources.[132]

Support for "non-dominant students" requires employing great numbers of teachers and administrators, few of whom are actually science teachers.

> The NGSS reinforce the need for collaboration among teachers of different specializations and subject areas beyond the traditional forms of collaboration. Science teachers need to work with special education teachers and teachers of ELLs [English language learners] in order to foster a deeper understanding of science. In addition, science, math, and English language arts teachers need to work together in order to address both the opportunities and demands for meaningful connections among these subject areas. Furthermore, collaboration needs to involve the entire school personnel, including teachers, administrators, counselors, etc. Utilization and development of social capital among school personnel is key to effective

132 *Next Generation Science Standards*, Appendixes, pp. 33-34; and see *Framework*, p. 324.

> implementation of the NGSS with all students, particularly students from non-dominant groups.[133]

The NGSS's call for such diversion of school resources is meant to expand dynamically.

> For example, future research may identify ways to make connections between school science and home/community for non-dominant student groups as they engage in the NGSS. Future research may explore how to utilize and allocate school resources to support student learning in terms of material resources, human capital, and social capital in relation to the NGSS.

> Effective implementation of the NGSS for all students, including non-dominant student groups, will require shifts in the education support system. Key components of the support system include teacher preparation and professional development, principal support and leadership, public-private-community partnerships, formal and informal classroom experiences that require considerable coordination among community stakeholders, technological capabilities, network infrastructure, cyber-learning opportunities, access to digital resources, online learning communities, and virtual laboratories. As the NGSS implementation takes root over time, these components of the education system will also evolve and change accordingly.[134]

The NGSS's commitment to *diversity* throughout Appendix D justifies a never-ending raid on the taxpayer's wallet—none of which is directed to hiring more competent science teachers, the most cost-effective means of increasing students' science knowledge.

133 *Next Generation Science Standards*, Appendixes, p. 34.
134 Ibid., p. 38.

Summary and Recommendations

Summary and Recommendations

The NGSS are the latest iteration in top-down, untested, and disastrous education reform touted by progressive activists, bureaucrats, and philanthropists. The botched rollout of the Common Core State Standards generally illustrates the bad track record of such imposed reforms.[135] National Assessment of Educational Progress (NAEP) math scores show the same percentage of eighth graders scoring proficient or better in 2017 under the CCSS as the year before their implementation in 2010—which suggests that the similarly unvetted CCSS mathematics curricula's negative effects entirely undid what should have been a decade of improvement in mathematics education.[136] America's experience with failed education reforms suggests it should expect little from the NGSS standards.

The NGSS actually do possess some good features. The addition of engineering standards, which introduce students to another field of science, is valuable. While we raise concerns about project-based education standards, we too recognize that inquiry-based learning can be beneficial if used as a pedagogical approach in moderation. Raising questions and encouraging curiosity is good. It appeals to the natural inclination of children to question everything in the world around them, and the naturally curious child may take a keen interest in science as a possible career pursuit. Children enjoy the process of discovery. In fact, some of the most valuable scientific discoveries are the result of curiosity and the inclination to ask questions. It is the imbalance of this approach that raises concerns, since overreliance on inquiry-based projects may not contribute to long-term memory of what is learned. After all, we're told that students can "just Google it."

The poor track record of education standards and outcomes at the hands of progressive education reformers should, of course, give us all

135 Peter Wood, ed., *Drilling through the Core: Why Common Core is Bad for American Education* (Pioneer Institute, 2015).

136 National Center for Education Statistics, NAEP Mathematics Report Card, U.S. Department of Education, https://www.nationsreportcard.gov/math_2017/nation/scores?grade=8.

pause when we consider the merit of any new set of education standards. For decades, America has put trust in education bureaucrats, not to mention well-meaning but misguided philanthropists like Bill Gates, to decide what is best for American schoolchildren. This has left us with unfulfilled promises of better educational outcomes, frustration by parents and their children with a de facto national curriculum in the form of CCSS, and consequent flat NAEP score growth since its implementation. Adopting the new science standards nationwide may offer nothing better. It should come as no surprise that, given the previous failures of constructivist math ("new math") in the mid-twentieth century, America has not fared any better with the constructivist mathematics of CCSS. The assurances of superior education resulting from math standards that were never piloted or vetted prior to implementation were simply hollow. How can the NGSS, without pilot testing or vetting, promise any better? We will not know the outcome of the NGSS until a generation of school children has completed its K-12 education. The potential cost of this educational gamble is much too high. The NGSS are an uncontrolled experiment in how to ruin science education in the name of reform.

Students should be able to engage in thoughtful analysis, sort through evidence, systematically analyze it, and then build arguments based on findings. Moreover, science education should be about discovering truth, not just assembling and regurgitating facts. Unfortunately, the NGSS abandon both. The NGSS severely neglect content instruction, politicize much of the content that remains, largely in the service of a *diversity and equity* political agenda, and abandon instruction of the scientific method. The NGSS will leave students unable to use the scientific method as a way to approach the truth. Furthermore, content knowledge is replaced with group projects, and (it appears, anyway) consensus answers to scientific questions, rather than verifiable evidence, are accepted without challenge. This is not real science, and it will most likely lead to more widespread issues of politicized groupthink and irreproducible science described by David Randall and Christopher Welser in their National Association of Scholars (NAS) report, *The Irreproducibility Crisis of Modern Science*.[137]

The NGSS fail to prepare students for undergraduate science coursework and to provide the basic scientific competency that all Americans should have when they graduate from high school, regardless of whether they proceed to a STEM career. NGSS proponents presume that college professors will compensate for the resulting deficits in K-12 science education. If they do, this will reduce undergraduate science courses to remedial classes. If they don't, a large number of unprepared college students, ill-served by the NGSS, will fail out of introductory science classes. Either way, the NGSS will do terrible damage both to college students and to colleges.

The most fundamental flaw of the NGSS is the missing essential science content. The *Framework for K-12 Science Education*, which was the foundation for the NGSS, summarizes the intended goal of the standards:

> The **overarching goal** of our framework for K-12 science education is to ensure that by the end of the 12th grade, *all* students **have some appreciation** of the beauty and wonder of science; possess sufficient knowledge of science and engineering to **engage in public discussions** on related issues; are careful **consumers** of scientific and technological information related to their everyday lives; are **able to continue to learn** about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology.[138] [Emphases added.]

This "overarching goal" makes it quite clear that the NGSS function as a set of what Ze'ev Wurman, former senior policy advisor at the U.S. Department of Education and outspoken critic of the NGSS, so

137 Randall and Welser, *The Irreproducibility Crisis of Modern Science.*
138 *Framework*, p. 1.

aptly calls *science appreciation standards* rather than rigorous educational standards.[139]

State education departments and boards of education should avoid adopting the NGSS—and, if they already have adopted it, immediately replace it with superior standards. The price of continuing with this educational folly is far too high.

The content errors, numerous omissions, imbalance in content, feasibility concerns with the implementation of integrated standards, obvious political dogma, and major shift in pedagogy should give decision-makers pause. To adopt an entirely new set of standards without any evidence of success through pilot testing is a dangerous educational experiment that is a disservice to all high school students, regardless of whether they plan to pursue STEM careers, but especially so for those who do.

Blanket adoption of the NGSS without careful comparison to other existing science standards—those rated higher than the NGSS by Fordham—is not beneficial. This should never happen, although many states have done so. It is time to engage in careful appraisal and ask questions about the science, or lack thereof, being taught in our schools.

We offer the following recommendations to states and districts:

1. If a state has not adopted new science standards and wishes to update and improve its existing standards, it should use the science standards graded as 'A' by the Fordham Review as a template. It should compare them with and find any helpful additions from the NGSS, such as the engineering standards that will introduce students to a new discipline, but with the understanding that students will likely not have the prerequisite mathematics preparation for true engineering standards in the upper grades.

139 Ze'ev Wurman, "Education to Raise Technology Consumers Instead of Technology Creators," Monolithic 3D, August 4, 2011, http://www.monolithic3d.com/blog/education-to-raise-technology-consumers-instead-of-technology-creators.

2. States that have already adopted the NGSS should compare them with the other state science standards graded as 'A' by Fordham and make changes, additions, and deletions as needed.
3. Chemistry and physics standards should be supplemented with previous existing standards to provide solid, complete high-school level courses for students who plan to pursue STEM in college.
4. States should strongly consider replacing CCSS mathematics with higher-level standards, such as the excellent and highly rated pre-CCSS California mathematics standards, to allow students to begin algebra in 8^{th} rather than 9^{th} grade. This will better prepare STEM-bound students as they enter college-level work.
5. States which choose to incorporate engineering in K-12 science education should adopt rigorous standards that require substantial amounts of mathematics.
6. States should allow, encourage, or require students to begin algebra in 8^{th} grade rather than 9^{th}, so that they may be prepared for rigorous high-school science classes.
7. School districts using the NGSS should encourage science teachers to use pedagogies that emphasize knowledge retention rather than project learning.
8. States should ensure that science instruction focuses its case studies on individual effort, scientific dissent, and paradigm shifts, selected from the most important episodes in the history of science, without reference to the race or sex of the scientists in question, although with preference for outstanding representatives of the American scientific and engineering tradition, such as Benjamin Franklin, Samuel Morse, Alexander Graham Bell, Othniel Charles Marsh, Josiah Willard Gibbs, Thomas Edison, Edwin Armstrong,

Edwin Hubble, Thomas Hunt Morgan, Claude Shannon, William Shockley, Linus Pauling, Richard Feynman, Robert Jarvik, and James Watson.

9. States should remove all political commitments from science education, especially those to *diversity*, environmentalism, and activism.
10. States should ensure that science standards steer students toward the full range of scientific careers and highlight how science and engineering can and should serve the American national interest.
11. States should ensure that science standards emphasize that devotion to science and engineering is its own reward, without reference to any "societal need," and that all research and design can and should aim above all for truth and beauty.

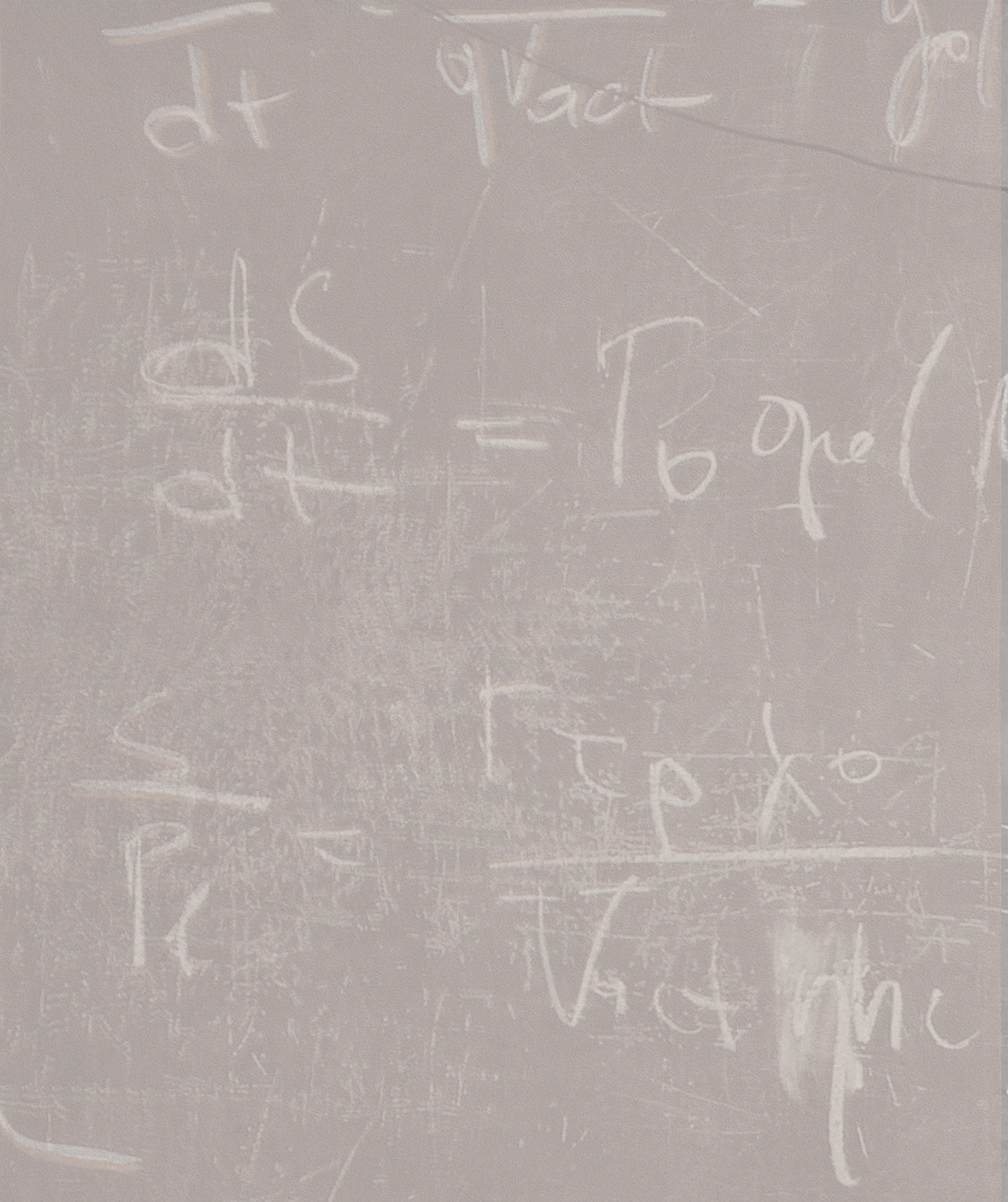
Conclusion

The warning issued in 1983 by Dr. Glenn Seaborg and his colleagues in the opening paragraphs of *A Nation at Risk* could have been a critique of the NGSS:

> …the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people…

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves … We have, in effect, been committing an act of unthinking, unilateral educational disarmament.[140]

140 *A Nation at Risk*, p. 7.



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