More Than a Method: The Scientific Method in Modern Science Education

Despite its relatively recent origins, "the scientific method" is ubiquitous in modern science education in the United States. From kindergarten to university, students are taught that science is characterized by a single method composed of distinct steps.[1] The exact number of steps can vary, and there are many possible variations on each step. Generally, the scientific method includes the following: observation, question, hypothesis, experiment, analysis, and conclusion.[2] While these steps are crucial in many areas of science, they are by no means representative of the actual breadth of scientific methods and practices. The creation and testing of a hypothesis are generally the most highly valued steps of the scientific method, yet many scientists work entirely within existing frameworks of knowledge and never make or test their own hypotheses at all.[3] Scientists now and in the past, like Charles Darwin and Albert Einstein, put together entire theories without ever experimenting or collecting quantitative data.[4] Many natural and social scientists use models or surveys as key forms of evidence rather than experimentation and use mathematical data analysis to form conclusions from their research. These are only a few examples of the many possible scientific methods. As a university student in my final year of my Science, Technology, and Society (STS) major, I was quite surprised when the first day of my introductory biology course involved learning the steps of the scientific method.[5] Throughout my STS studies I had begun to think of the scientific method as something

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[1]Brian Hepburn and Hanne Andersen, "Scientific Method," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Summer 2021 (Metaphysics Research Lab, Stanford University, 2021).
[2] Ibid.
[3] Kieran Lim, "Teaching the Scientific Method in the Curriculum," *Chemistry in Australia* 2012 (April 1, 2012): 39.
[4] Cowles, Henry M. The Scientific Method: An Evolution of Thinking from Darwin to Dewey. Cambridge, Massachusetts: Harvard University Press, 2020, 18.
[5]James R. Morris, Daniel L. Hartl, Andrew H. Knoll, Robert Lue, Melissa Michael, Andrew Berry, Andrew A. Biewener, Brian B. Farrell, and Noel Michele Holbrook. *Biology: How life works*, 2nd ed. New York, NY: WH Freeman, 2016.

only taught to children as a preliminary way of thinking about science; I certainly did not expect to be quizzed on the correct order of steps in the scientific method in a university class. I realized that day that it is far too easy for STS scholars to forget that the scientific method still reigns over the majority of introductory-level science education in the US. A survey of UPS students that I conducted during my research supports this claim: every one of my respondents reported having learned the scientific method in school, and 62 percent reported learning it at university (see Figure 5). My question is: why is the scientific method still so dominant when most scholars and experts in science communication and pedagogy seem to strongly disagree with this approach to science education, and how does this reality impact public attitudes towards science?

This paper examines the value of the scientific method and arguments for and against its inclusion in education. I focus my analysis on the present-day United States, but I also discuss some of the historical aspects of the origins of the scientific method and modern science educational standards. I argue that historical and contemporary discourse on the scientific method clearly demonstrates that it is neither an accurate depiction of science nor an effective educational tool. The scientific method has become not only a teaching strategy, but a justification for the validity and uniqueness of the scientific way of knowing. Its existence as a source of social authority reinforces the continued prevalence of the myth of the scientific method, which is problematic in a world where science literacy is becoming increasingly important for everyone.

Many people have struggled to find a unified definition for science, but none have truly succeeded.[6] What are the defining characteristics of science that set it apart from other ways of

[6] Hepburn and Andersen, "Scientific Method."

knowing? This question, known as the demarcation problem, has puzzled philosophers for many years.[7] Many scientists and philosophers, including Karl Popper and John Dewey, have tried to invent tests or rules that define science, but none have proven satisfactory. Sets of epistemological requirements or methodological steps invariably turn out to be either too narrow or too broad to be useful or accurate.[8] We all know science as a unique force in our society, but can we come up with an acceptable definition of what it is? The scientific method is often labeled a "myth" because there is no one true scientific method, but it is also mythical in its social and epistemological power. The scientific method tends to be portrayed as the soul of scientific authority: "often, reference to scientific method is used in ways that convey either the legend of a single, universal method characteristic of all science, or grants to a particular method or set of methods privilege as a special 'gold standard.'"[9] Science is special in many ways, but the scientific method is not the reason why. Science is unique because of its track record in giving us practical and reliable information about the natural world, and that does not come from a single method. Science is also unique because of the scientific community's focus on avoiding bias and making sure that scientific information is reliable before it is published. Although it is impossible to truly avoid bias, the structure of the global scientific community encourages open minded and careful research.[10] In addition, the institution of the peer review process encourages scientists to do careful work before attempting to publish, and thorough review prevents bad science from being published by trustworthy sources or replicated.[11]

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[7] Hepburn and Andersen, "Scientific Method."
[8] Cowles, *The Scientific Method*, 1.
[9] Hepburn and Andersen, "Scientific Method."
[10] Partha Dasgupta and Paul A. David, "Toward a New Economics of Science," *Research Policy*, Special Issue in Honor of Nathan Rosenberg, 23, no. 5 (September 1, 1994), 514.
[11] Ibid.

The scientific method can be found in almost all types of science education. It is taught in grade school, explained in educational videos, modeled in science fairs, and diagrammed in textbooks.[12] While the scientific method does represent some of the general goals of scientific inquiry, such a narrow and linear framework cannot possibly describe the realities of science in all fields. Mark Windschitl, a professor of science education at the University of Washington, argues that

> The simplicity of the Scientific Method obscures the complex methodological strategies (e.g., developing laboratory situations analogous to real-world conditions), and involved logic (e.g., coordinating theoretical models with multiple sets of multifaceted, partially conflicting data) of authentic science. Furthermore, analyses of practice in scientific communities have shown that there is no universal method and that science inquiry can take a variety of forms.[13]

Windschitl's argument is representative of the kinds of criticisms frequently leveled at the scientific method by many science communication experts and professional scientists. Every field of science has its own set of methods suited to its focus, every scientific organization has its own approach to scientific inquiry, and every scientist has their own way of thinking about their work.[14] Science is a long, complex, often repetitive process involving many ways of thinking and obtaining information, and it has changed drastically over time. The methods involved in using high-tech instruments, AI, and computer modeling are all new and different, yet vital to modern science. Today, science is becoming ever more involved in everyday life due to advancing technology and science-related political concerns. A basic level of science literacy is now necessary in order to make informed personal and political decisions, and an understanding of how science is done is an important part of science literacy. Many modern curricula focus

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[12] James R. Morris et. al., Biology*: How LIfe Works,* 3.

[13] Mark Windschitl, "Folk Theories of 'Inquiry:' How Preservice Teachers Reproduce the Discourse and Practices of an Atheoretical Scientific Method," Journal of Research in Science Teaching 41, no. 5 (2004): 483.

[14] John L. Rudolph, *How We Teach Science - What's Changed, and Why It Matters*. Harvard University Press, 2019.

strongly on methods, which are not necessarily limited to *the* scientific method, but it is still far too prevalent. Students who learn it are often left without knowledge of authentic scientific practices or of the real reasons science should be trusted.[15] Therefore, it is important that we figure out more effective ways to approach science education.

Many recent science education standards and curricula are designed with an explicit intent to move science education away from the memorization of facts and towards a focus on scientific thinking and methodology.[16] This is not necessarily a new trend--in the late 1800s, philosopher John Dewey's influential science pedagogy was focused on teaching both "material and methods."[17] His curriculum was centered on student-led experimentation, similar to the majority of contemporary science curricula.[18] Despite these historical facts, in today's world focusing classroom education on memorizing scientific concepts and theories is often seen as an old-fashioned pedagogy.[19] Many educators argue that this approach is ineffective and does not leave students with the scientific thinking skills supposedly needed for modern life, while students often find fact-based learning boring and hard to remember.[20] Because modern science has become so specialized within each field, truly understanding any new science requires a massive amount of previous knowledge. Professor of education Grace Reid argues that memorization of scientific facts is no longer useful science education, and that it does not make a

[15] Brian Wynne, "Public Engagement as a Means of Restoring Public Trust in Science - Hitting the Notes, but Missing the Music?," Community Genetics 9, no. 3 (May 2006), 215.
[16] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, United States: National Academies Press, 2012.
[17] Cowles, *The Scientific Method*, 255.
[18] Ibid.
[19] National Research Council, *A Framework for K-12 Science Education*, 40-43.
[20] Grace Reid and Stephen P. Norris, "Scientific Media Education in the Classroom and beyond: A Research Agenda for the next Decade," Cultural Studies of Science Education 11, no. 1 (March 1, 2016), 160.

long-term impact on students' scientific literacy.[21] While I agree with Reid that an overemphasis on detailed scientific information (that students are likely to forget) is not an ideal strategy for science communication, I would argue that it is definitely important for students to learn at least some basic scientific facts, especially ones which can help them understand their life experiences. What some refer to as "scientific thinking" --critical thinking, the ability to evaluate claims, and healthy skepticism, are invaluable skills which should be taught in schools. However, general trends in science education pedagogy somewhat miss the mark on this issue, and many "methods-based" or "practice-based" approaches often end up looking a lot like "the scientific method."[22]

Students who learn the scientific method during their education and then observe the varied and imperfect nature of science in the real world may be harshly disillusioned, resulting in loss of trust in the sciences. Despite a national focus on STEM education, basic science and health literacy among the American public remains low–less than half of US adults know that antibiotics only work on bacteria.[23] n the modern world, where our society is facing global crises like climate change and the COVID pandemic, it is increasingly crucial for everyone to be able to understand and fairly evaluate scientific information. The scientific method is a drastic oversimplification of a crucial way of knowing, and its continued presence in science education only hinders educators' goals of improving science literacy and public trust in science.[24]

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[21]Grace Reid and Stephen P. Norris, "Scientific Media Education in the Classroom and beyond," 161.

[22] Charles R. Ault, *Challenging Science Standards : A Skeptical Critique of the Quest for Unity* (Lanham, Maryland : Rowman & Littlefield, 2015).

[23] Brian Kennedy and Meg Hefferon, "What Americans Know About Science," *Pew Research Center Science & Society* (blog), March 28, 2019, https://www.pewresearch.org/science/2019/03/28/what-americans-know-about-science/.

[24] John L. Rudolph, *How We Teach Science,*

The History of the Scientific Method:

Contrary to common assumptions, the scientific method, at least as it is often described in textbooks as a set of numbered steps that is and should be followed by everyone who desires to "do science," is a relatively new phenomenon.[25] In fact, the scientific method as we know it today did not exist until the early twentieth century. Throughout the nineteenth and early twentieth century, society's picture of the meaning of science changed drastically.[26] Historian of science Henry Cowles writes "the transformation of science from product to process, from thought to thinking, was one of the crowning achievements of the nineteenth century."[27] During the industrial revolution, the results of scientific and technological development became extremely visible. Science was slowly gaining influence as a discipline, and many philosophers and scientists felt that the nature of scientific thinking was crucial to improving science's social and epistemological status. Cowles calls the mid-1800s "the age of methods" because of the shift from a general focus on science as a knowledge base to science as a process.[28] Scientific inquiry was labeled as a process which came somewhat naturally to humans but could be further cultivated through induction and objectivity.[29]

Although the scientific method as we know it did not yet exist, the unification of science served very familiar social purposes. STS scholar and educational policy professor John Rudolph, whose work on the development of the scientific method influenced Cowles', writes that

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[25] James R. Morris et. al., Biology*: How Life Works,* 6.
[26] Cowles, *The Scientific Method*, 2.
[27] Ibid., 18.
[28] bid., 10.
[29] Ibid.

> these early portrayals of science, as governed by a well-defined method capable of producing certain knowledge, were used primarily to enlist public support for the fledgling profession as it jokeyed for status with the more established social institutions of the time…an emphasis on validity of scientific methods served the political needs of science to legitimate science, to defend it from conservative religious criticism, and to affirm its broad cultural importance.[30]

The effects of this transformation are still visible in the scientific method's existence as a social authority, as modern educators and even scientists themselves often appeal to the supposedly descriptive, unbiased, and reliable scientific method in order to strengthen their scientific claims. As one biology textbook demonstrates, we are often told we should trust science and scientific institutions purely because of "the power of the scientific method."[31]

Many historians point to the book *How We Think* by American philosopher John Dewey as the beginning of today's scientific method. In his book, Dewey attempted to condense a "complete act of thought" into a list, providing a general structure for reflective thinking:

> Upon examination, each instance reveals, more or less clearly, five logically distinct steps: (*i*) a felt difficulty; (*ii*) its location and definition; (*iii*) suggestion of possible solution; (*iv*) development by reasoning of the bearings of the suggestion; (*v*) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief.[32]

This list contains some of the key elements of the scientific method: finding a problem, making observations, experimentation, and conclusion. Its influence on the scientific method is also clearly recognizable due to the similar progressive list structure. Dewey was not attempting to describe science with his list at all--just a useful method of thinking. His list was never intended to be used as a strict progression or a method at all, nor was it specific to any one subject area.

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[30] John L. Rudolph, "Epistemology for the Masses: The Origins of 'The Scientific Method' in American Schools," *History of Education Quarterly* 45, no. 3 (2005), 345.
[31] James R. Morris et. al., Biology*: How Life Works,* 6.
[32] John Dewey, "How We Think," https://www.gutenberg.org/files/37423/37423-h/37423-h.htm, accessed December 16, 2021, 72.

Taken out of context, Dewey's list eventually gave rise to the scientific method, a list of rules that set science apart from ordinary, everyday thinking."[33] Dewey himself was an educator and was involved in science education, but he was not personally involved in the process of creating the scientific method. However, he did contribute to the rise of "the laboratory method," a process-focused and hands-on form of science education which became popular in the late nineteenth century.[34] The laboratory method signaled the beginning of a transition from content and memorization focused science education to the still-prevalent methods-based science education in the US.[35] This new focus on methods in science education created the perfect atmosphere for the rapid adoption of the scientific method.

Another crucial force in the development of the scientific method was "the burgeoning science textbook industry."[36] US textbook authors modified Dewey's list and used it as a new methodological basis for curricula and teacher's guides, rapidly spreading the scientific method throughout science curricula and therefore throughout scientific discourse.[37] Dewey's new straightforward set of steps replaced more elusive and complex descriptions of science, which textbook authors had drawn from historical philosophers and scientists like Frances Bacon and centuries John Stewart Mill.[38] As public schools continued to grow throughout the nineteenth and twentieth centuries, the scientific method took a firm hold over US science education. However, not everyone at the time was as enamored with the scientific method as were textbook

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[33] Cowles, *The Scientific Method,* 3.
[34] Rudolph, "Epistemology for the Masses," 348.
[35] Cowles, *The Scientific Method,* 349.
[36] Ibid., 265.
[37] Rudolph, "Epistemology for the Masses," 369.
[38] Ibid.

authors and schoolteachers. A collection of Harvard scientists, led by Harvard president James B. Conant, harshly criticized the scientific method, writing,

> "Nothing could be more stultifying, and, perhaps more important, nothing is further from the procedure of the scientist than a rigorous tabular progression through the supposed 'steps' of the scientific method, with perhaps the further requirement that the student not only memorize but follow this sequence in his attempt to understand natural phenomena."[39]

Similar criticisms of the scientific method have long been common among science scholars and many scientists, but the scientific method has largely remained unscathed, especially in primary education. Along with the methods-focused momentum of the nineteenth century, the textbook industry and public education's love for the scientific method catapulted a mutated form of Dewey's list into the minds of students and teachers, where it has remained ever since.

During the twentieth century, scientific institutions and methods continued to grow in their social, political, and epistemological power. Instrumental philosophy (a school of thought that focuses on finding effective models and methods in science rather than absolute truth) further encouraged a focus on methods as a source of control and power-- "science was more powerful than ever, in terms of both its capacity to alter the natural and social worlds and the authority it commanded as something to which people could appeal."[40] Another approach to the philosophy of science, falsificationism, also helped solidify science's social power. One of the most influential philosophers of science of the twentieth century, Karl Popper, proposed the idea of falsification as the ultimate solution to the demarcation problem. Popper argued that if there is

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[39] Committee on the Objectives of a General Education in a Free Society, General Education in a Free Society: Report of the Haward Committee (Cambridge: Harvard University Press, 1945), 158.

[40] Cowles, *The Scientific Method,* 279.

a way to test a scientific theory or hypothesis and prove it to be false, it is good science.[41] Bad science cannot be falsified, because there is no way to test it, and its proponents always find a way to circumvent being wrong. This new definition of science proved valuable in many circumstances, but it is not a perfect solution to the demarcation problem.[42] Popper's falsificationism was extremely influential and helped cement the idea of experimentation and hypothesis testing as being central to "real" or "good" science. Falsifiable science gained even more social authority due to this new test of science's reliability. Despite the popularity of falsificationism and its lasting influence on the philosophy of science, the scientific method's definition of "good" science survived and still thrives in twentieth century science education.

As science's social power grew and the scientific method became more ingrained in science education and the minds of students and teachers, it became increasingly tied to science's epistemological authority. Over time, the scientific method became, in some ways, the ultimate source of that authority.[43] Modern science education continually appeals to the scientific method or elements of the scientific method as the reason why students should put their trust in science, and in turn, students are told to trust the scientific method because science has proven over time to be an effective way of knowing.[44] This circular argument is common in modern science

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[41] Stephen Thornton, "Karl Popper," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Fall 2021 (Metaphysics Research Lab, Stanford University, 2021), https://plato.stanford.edu/archives/fall2021/entries/popper/.
[42] Thornton, "Karl Popper."
[43] Charles R. Ault, *Challenging Science Standards : A Skeptical Critique of the Quest for Unity* (Lanham, Maryland : Rowman & Littlefield, 2015), 4.
[44] James R. Morris et. al., Biology*: How Life Works,* 6. and "The Scientific Method (Video) | Khan Academy." and Bill Nye. "Pseudoscience." Accessed September 24, 2021. https://billnye.com/the-science-guy/pseudoscience. and Windschitl, Mark. "Folk Theories of 'Inquiry:' How Preservice Teachers Reproduce the Discourse and Practices of an Atheoretical Scientific Method." *Journal of Research in Science Teaching* 41, no. 5 (2004): 481–512.

curricula and is proving very difficult to remove, despite the attempts of many curriculum designers and science scholars.

The Scientific Method in Contemporary Education:

Today, US science education remains strongly focused on methods. The scientific method has been criticized by science scholars since it first became mainstream, but its popularity in education has only recently begun to decline.[45] The self-sustaining relationship between science's authority in society and the scientific method has kept elements of the scientific method (such as emphasis on hypothesis-driven physical experimentation and a alive and well even in curricula that attempt to avoid it. The Next Generation Science Standards (NGSS), published in 2013, are an important example of the dominant themes in modern science education curricula, including a focus on methodology, student-led experimentation, and laboratory-based learning. The NGSS were created by the National Research Council (NRC) and based on the NRC's "A framework for K-12 science education," which forms the pedagogical basis for the 2013 standards. According to the NGSS, "forty-four states (representing 71% of U.S. students) have education standards influenced by the Framework for K-12 Science Education and/or the Next Generation Science Standards."[46] The framework recommends a practices-based approach to science education and also explicitly discourages teaching the scientific method.[47] The NRC writes 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

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[45] Rudolph, "Epistemology for the Masses," 341.
[46] "NGSS Hub," accessed December 19, 2021, https://ngss.nsta.org/why-standards-matter.aspx.
[47] *"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" at NAP.Edu*, accessed September 24, 2021, https://doi.org/10.17226/13165, 43.

method—or that uncertainty is a universal attribute of science."[48] Interestingly, the previous generation of science education standards from the NRC, i.e., the 1996 National Science Education Standards (NSES), also discouraged the use of the scientific method.[49] If the NSES advised against the scientific method in 1996, why is it still so prevalent, and why do the NGSS still need to discourage its use? Avoiding the scientific method's limitations is a goal supported by many science educators, but when the standards are translated to actual classroom activities, the scientific method often still manages to sneak in.

The NGSS provides a continuous set of curriculum guidelines for every grade from elementary to high school. Most NGSS units are heavily focused on student-led observation, experimentation and modeling. Students are asked to construct their own experiments, interpret data sets, and participate in discussions. Often, the standards describe activities where students make observations of the subject material and then design their own experiments or models to demonstrate their analysis. For example, the second-grade chemistry and physics module suggests various activities through which to teach various scientific principles–this unit focuses on changes in matter, and suggests a demonstration of boiling an egg to model an irreversible change. Instruction for older students tends to be more hands-on–one of the three core elements of the middle school unit on chemical reactions is the following project: "Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes."[50] Factual content is generally only discussed in conjunction with suggested

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48 *"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" at NAP.Edu*, accessed September 24, 2021, https://doi.org/10.17226/13165, 43.

49 "National Science Education Standards," accessed December 19, 2021, http://www.csun.edu/science/ref/curriculum/reforms/nses/.

50 "MS.Chemical Reactions | Next Generation Science Standards," accessed December 19, 2021, https://www.nextgenscience.org/topic-arrangement/mschemical-reactions.

interactive learning exercises. Although "process-based" curricula like the NGSS are often designed with the intent of avoiding the confines of the scientific method or rote memorization, the "processes" they teach tend to mimic elements of the scientific method and do not include diverse scientific approaches and methods.[51]

Each subject area in the suggested curriculum includes three categories of key ideas: "Science and Engineering Practices," Disciplinary Core Concepts," and "Crosscutting Concepts."[52] The "Science and Engineering Practices" category lists connections with engineering and technology, including data analysis and model building. while the "Crosscutting Concepts" sometimes brings in connections to "the nature of science," with some brief philosophical and epistemological discussions of scientific knowledge.[53] While the attempts of the NGSS to connect science curricula to the philosophy of science and technology are valuable, its curricula barely touch on the full range of what doing science can mean. The NGSS specifically discourage teaching the "scientific method," but they do not delve into why teaching it is inadvisable, and the guidelines themselves do not encourage individual teachers to expand beyond the scientific method.[54] For example, the high school evolution unit suggests that students "construct an explanation based on evidence" and "evaluate the evidence" surrounding natural selection.[55] Although the authors do not use the word "experiment" or "observation," translated to real classrooms, these kinds of projects will not prevent teachers from encouraging

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[51] Ault, *Challenging Science Standards*, 2.
[52] "NGSS Hub," accessed December 19, 2021, https://ngss.nsta.org/AccessStandardsByTopic.aspx.
[53] "HS.Natural Selection and Evolution | Next Generation Science Standards," accessed December 19, 2021, https://www.nextgenscience.org/topic-arrangement/hsnatural-selection-and-evolution.
[54] *"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" at NAP.Edu*, accessed September 24, 2021, https://doi.org/10.17226/13165, 43.
[55] "HS.Natural Selection and Evolution | Next Generation Science Standards," accessed December 19, 2021, https://www.nextgenscience.org/topic-arrangement/hsnatural-selection-and-evolution.

students to follow the scientific method, or prevent students from applying what they have already learned about the scientific method to their projects.[56] While the NGSS's "practices" are crucial in many kinds of science and are undoubtedly useful for students to learn, they remain essentially as limited in scope as the scientific method does. However, one crucial practice not discussed in the scientific method but heavily emphasized in the NGSS is modeling, which is vital to many modern sciences. Physics, climatology, biology, and nearly every other science use models in some way, some more than others, and they are becoming increasingly useful and commonplace with the improvement of computer simulation technology.[57] Social sciences like economics and sociology also often rely on models, and these forms of science are generally ignored entirely by STEM curricula, including the NGSS. Although the inclusion of modeling does not make up for the NGSS's failure to truly discourage the teaching of the scientific method, its inclusion of engineering practices and modeling demonstrates the potential for national education standards to continue to improve in the future.

Arguments of Modern Science Scholars and Educators:

Many modern science scholars, education professionals, and scientists object to the scientific method, and some have proposed alternative options for science education. Professor Mark Windschitl proposes an alternate way of teaching scientific thought which he calls "Model-Based Inquiry."[58] He argues that teaching the scientific method in schools creates a fundamental misunderstanding of science that students carry throughout their lives, even when they become scientists or science teachers themselves. One of Windschitl's main issues with the scientific

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[56] Ault, *Challenging Science Standards*, 6.

[57] Ibid., 3.

[58] Mark Windschitl, Jessica Thompson, and Melissa Braaten, "Beyond the Scientific Method: Model-Based Inquiry as a New Paradigm of Preference for School Science Investigations," *Science Education* 92, no. 5 (2008): 945., https://doi.org/10.1002/sce.20259.

method is that it does not involve situating the topic in its scientific context before beginning an investigation and that it often does not involve a reflection or analysis stage.[59] This lack of connection to a broader scientific framework causes students to view science as an isolated and methodical practice. Viewing science as a collection of individual progressions through the scientific method damages science literacy, as students may never comprehend the interconnected web of constantly changing knowledge that science really is. Model based inquiry is intended to include many different ways of doing science through a broad set of the “features” of science, and to encourage reflective thinking and diverse methods.[60] Windschitl’s vision of science education is similar to the ideals of the NGSS, which also includes an emphasis on modeling. Model-based inquiry has promise as an element of science curricula, but I argue that model and practice-based learning does not do enough to teach students that science has many different methods and is not a one-way, infallible process. The inclusion of models in science curricula is a step forward, but that alone is not enough to give students a real understanding of the realities of modern science, nor to uproot the mythic unity of the scientific method.

While some science education experts encourage the use of the NGSS, in *Challenging Science Standards, a Skeptical Critique of the Quest for Unity (2015),* teacher and professor of science education Charles Ault argues that the methods and process-based approaches highlighted in national science education standards, like the NGSS and other science curricula, are basically just re-labeling the scientific method with a new name.[61] Ault writes that process-based approaches often have the same kind of issues that teaching the scientific method does—

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[59] Windschitl, Thompson, and Braaten, “Beyond the Scientific Method,” 948.
[60] Ibid.
[61] John Falk, *Science Outside of School*. Ways of Knowing in Science and Mathematics Series, edited by Falk, John H. John Howard, Elizabeth Donovan, and Rosalie Woods, 3-20. New York: Teachers College Press, 2001. and Ault, *Challenging Science Standards*, 33.

they do not show why certain methods are selected and used. Instead, they just give a brief overview of the possible options.[62] Standards like the NGSS present themselves as new ways of teaching that are adapted to modern life but in reality, the process of trying to consolidate all of science into any one set of practices does not work in any situation, regardless of whether it is labeled as the scientific method or something else. Ault criticizes the NGSS's "crosscutting concepts" and "science and engineering practices," labeling them as a continuation or even a resurrection of the twentieth century push for a unified vision of scientific inquiry.[63]

Ault and several other science scholars, including Rudolph, argue that educators' attempts to condense all the varied fields and types of science into a single, teachable method only complicates the issue further by creating unrealistic expectations.[64] Every type and field of science uses different methods and processes, from computer modeling to surveys to artificial intelligence. Educating students on these diverse approaches may be difficult, but it is necessary in order to give students the level of science literacy demanded by modern life. When students are taught a single method and then witness science operating outside of that set process, they may start to distrust science, which is the opposite of what science educators want.[65] For example, imagine a person who has grown up believing that science must use the scientific method, or it is not real or valid science. This person then watches scientific institutions including the CDC and the WHO change their conclusions on the value of wearing masks during a pandemic multiple times and starts to doubt the truth of scientific statements made by authorities. According to "the scientific method," the scientists should have done experiments,

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[62] Ault, *Challenging Science Standards*, 37.
[63] Ibid., xvi
[64] Ibid. and Rudolph, *How We Teach Science - What's Changed, and Why It Matters*.
[65] Ault, *Challenging Science Standards*, 38.

repeated them, made a conclusion, and then told everyone about it. First of all, the initial claims scientists made did not come from direct experimental evidence with COVID, they came from prior knowledge about viral transmission.[66] When they learned more about COVID specifically, the scientists changed their conclusions about wearing masks. That process does not follow the scientific method--there was no experimentation, no repetition, and the conclusions changed over time. If science had been done the "right way," it should have been right the first time. The scientific method does not include large scale trial and error, and often, if it is presented as a linear progression, it does not include the possibility of revision at all. The person who observed these changes in masking recommendations might then conclude that the scientists had never done science "right" and probably were not right the second or third time they made conclusions either. This all-or-nothing view of the scientific process is a fundamental misunderstanding of science and the meaning of scientific proof.

Scientists themselves also often make similar arguments against the scientific method, and some even complain that its authoritative presence constricts their ability to do science the way they feel is best for their own work.[67] One UPS science professor told me that he often essentially pretends to have followed the scientific method in order when presenting his work, but really he does not follow it at all. Many scientists feel this pressure to conform to the scientific method and adapt their scientific publications to reflect the scientific method even if they went about their research in a very different way. Historian and philosopher of science Jutta Schickore discussed this phenomenon in her article "Doing Science, Writing Science." She

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[66] Christina Farr, "Why Scientists Are Changing Their Minds and Disagreeing during the Coronavirus Pandemic," CNBC, May 23, 2020, https://www.cnbc.com/2020/05/23/why-scientists-change-their-mind-and-disagree.html.
[67] Siu Ling Wong and Derek Hodson. "More from the Horse's Mouth: What Scientists Say about Science as a Social Practice." International Journal of Science Education 32, no. 11 (July 15, 2010): 1431–63.

establishes the well-documented existence of a “mismatch” between what scientists actually do and what they publish in scientific journals.[68] Schickore argues that scientists often change the way they present their research in order to make it easier to analyze logically and draw conclusions from.[69] The practice of re-arranging science in a way that makes it more digestible may be one reason that it is sometimes difficult to convince people that many scientists do not follow the scientific method, as the evidence is not always there in writing.

Why is the Scientific Method Still so Dominant in Contemporary Science Education:

Grade School Curricula:

Why does the scientific method continue to be taught in both primary and secondary education in the United States? It may be appealing to educators because it provides a concrete and consistent structure for science education without deviating from the pedagogical goals of “practice-based” learning. This desire to teach students to think scientifically leads many educators to teach the best tangible description of scientific inquiry they can think of--the scientific method. The simple, authoritative structure of the scientific method is one of the main reasons it so quickly became entrenched in science education.[70] This unified method of teaching and describing science also services bureaucratic desires to create consistent and easily assessable curricula. Despite the desire demonstrated by the NRC for an interactive and engaging learning environment, public school curricula must still teach students the kind of information it is possible to include in a standardized. test.[71] Public school science curricula are limited by the

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[68] Jutta Schickore, “Doing Science, Writing Science*,” *Philosophy of Science* 75, no. 3 (2008): 323–43, https://doi.org/10.1086/592951.
[69] Ibid., 325.
[70] Rudolph, *How We Teach Science - What's Changed, and Why It Matters,* 4.
[71] Ibid.

function of the public school system as a whole, and despite the pedagogical goals of standards writers, teachers must still "teach to the test." Very often, teaching science in a consistent and testable way looks a lot like teaching "the scientific method."

Teachers face additional pressure to teach the scientific method when they use textbooks. Many textbooks in all grade levels still begin with an introduction to "the scientific method," and many include diagrams showing a strict linear progression (see Figure 1).[72] As a part of my research, I created a survey containing questions about people's experiences with learning the scientific method in school. I sent the survey out to STS and chemistry students at UPS and received around 60 responses. The survey included questions about what grade levels people learned the scientific method in, whether their textbooks included it, and whether it was taught as a cycle or a linear progression. Although it is a relatively small sample of respondents, my survey yielded insights into my peers' experiences with the scientific method that I could not have obtained elsewhere. My survey revealed that 78 percent of my respondents had at least one science textbook that explicitly taught the scientific method at some point during their formal education (see Figure 3). Since textbooks are often used as a basis for entire curricula, they are a major contributor to the maintenance of the myth of "the scientific method." Portraying science in this limited way, even if the scientific method is not discussed outside of textbook readings (perhaps thanks to NGSS influence), sets a precedent for students' mindsets when approaching science in the future. Repeated exposure to similar textbooks would then further cement the scientific method in students' minds. One 1997 chemistry textbook establishes the scientific

[72] James R. Morris, Daniel L. Hartl, Andrew H. Knoll, Robert Lue, Melissa Michael, Andrew Berry, Andrew A. Biewener, Brian B. Farrell, and Noel Michele Holbrook. *Biology: How life works*, 2nd ed. New York, NY: WH Freeman, 2016.

method as similar to the process we might use to answer everyday questions, such as finding the best way to get to school. This textbook includes a linear diagram of the scientific method that includes the theory stage emerging from a repeating process of observation and experiment (see Figure 1).[73] The textbook states that there is technically more than one scientific method, and that "the scientific methods are only as effective as the humans using them."[74] Despite these attempts at depicting diversity, the intro section continuously refers to the "generic" scientific method.[75]

Although this is a common trend in textbooks, not all follow the pattern. A 1992 biology textbook includes the following statement in its introductory section:

> Biology is unified in its methods of acquiring knowledge of the living world. Although science writers frequently refer to a formal set of procedures called 'the scientific method,' a careful assessment of the activities of scientists, both living and dead, indicates clearly that there is no single 'scientific method' in biology or in any other science. Biologists, like all scientists, are interested in different questions and use methods that are appropriate for answering the questions at hand."[76]

This textbook, co-written by historian of science Paul Farber, single handedly does a better job of explaining the diversity of science than the majority of introductory science texts I have experienced in my lifetime.[77] Farber's relatively unusual approach is not necessarily representative of biology--my 2016 biology textbook describes a rigid method of five steps, containing an internal cycle of hypothesis revision but no indication of the crucial larger-scale cycles of scientific inquiry. The 2016 textbook even uses various examples "to emphasize the *power* of the scientific method," clearly teaching students that the scientific method is not only a

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[73] James R. Morris et. al., Biology*: How LIfe Works,*7.
[74] Stephen Zumdahl, *Chemistry*, 4th ed. (Houghton Mifflin, 1997).
[75] Ibid.
[76] Paul Farber, Mix, Michael C. and King, Keith I. Biology: The Network of Life. New York, NY: Harper Collins Publishers 1992.
[77] Unfortunately, it was outcompeted by a more mainstream biology textbook and did not see much use.

useful tool, but a uniquely powerful formula that endows scientific knowledge with social and epistemological authority.[78]

Science Media:

The myth of the scientific method is not propagated by formal education alone. Many children and adults are frequently exposed to various forms of educational (to varying degrees) science media, including television shows, documentaries, and video games. People are likely to run across science media frequently, in jobs, school, and extracurricular activities. Television, movies, and video games have a unique power to engage learners' attention, and it is important that they are quality sources of science education.[79] Programs like *Nova*, *Bill Nye the Science Gu*y, *Cosmos*, and many many more often dramatize science to make their educational material more interesting, and are generally more flashy than educational videos like *Khan Academy* or *SciShow*, featuring musical scores and CGI.

In recent years, a strong governmental focus on STEM education initiated by the Obama administration has brought science education to the forefront of public discussions on modernizing public school curricula.[80] Organizations like the NRC often cite economic success as a key motivation for improving STEM education, while writing guidelines that encourage teaching scientific thinking skills. The NGSS carefully includes technology and engineering related discussions in many steps of their curriculum. According to the NRC's framework, the

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[78] Morris, James R., Daniel L. Hartl, Andrew H. Knoll, Robert Lue, Melissa Michael, Andrew Berry, Andrew A. Biewener, Brian B. Farrell, and Noel Michele Holbrook. Biology: How life works, 2nd ed. New York, NY: WH Freeman, 2016. *my italics* add figure

[79] Fernando Vidal, "Introduction: From 'The Popularization of Science through Film' to 'The Public Understanding of Science.'" Science in Context 31, no. 1 (March 2018): 1–14.

[80] "STEM for All," whitehouse.gov, February 11, 2016, https://obamawhitehouse.archives.gov/blog/2016/02/11/stem-all.

addition of engineering-based content is intended to encourage children to follow more practical STEM careers, which the NRC views as a serious priority in US science education.[81] Students who choose to pursue STEM are often interested in the facts and subject material, and less philosophically engaged with scientific methodology and thinking skills. This desire to push students into STEM can create educational media and events that push exciting scientific facts and fun experiments intended to engage audiences at the cost of authenticity. Hypothesis, experimentation, and analysis, the central aspects of the scientific method are far more appealing to children than the reality that science does not always involve experimentation at all, or that scientists often work in teams on existing research and do not always create their own hypotheses or even test hypotheses. Therefore, the recent push for STEM education may be less beneficial to overall science literacy than is expected.

One extremely popular educational channel, *Khan Academy*, is often used both by teachers as a supplement to school curricula and by children and adults seeking to educate themselves outside of formal schooling. *Khan Academy's* collection of educational videos includes a video titled "The Scientific Method." The description reads:

> at the core of biology and other sciences lies a problem-solving approach called the scientific method. The scientific method is used in all sciences—including chemistry, physics, geology, and psychology. The scientists in these fields ask different questions and perform different tests. However, they use the same core approach to find answers that are logical and supported by evidence.[82]

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[81] *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" at NAP.Edu*, accessed September 24, 2021, https://doi.org/10.17226/13165, 2.

[82] *The Scientific Method*. Films On Demand. Accessed September 17, 2021. https://fod.infobase.com/PortalPlaylists.aspx?wID=103122&contentID=N6IAzlugWw0&channel=KhanAcademy&chnID=55.

Khan argues that the scientific method is a common-sense way of thinking about the world, an . In the video, Khan explains the five steps of the scientific method and works through the example of investigating why saltwater and freshwater freeze at different temperatures. Khan's five steps are the following: "make an observation, ask a question, form a hypothesis or testable explanation, make a prediction based on the hypothesis, test the prediction, and iterate: use the results to make new hypotheses or predictions."[83] Because this list includes the iteration step which transforms the stepwise method into a repeating cycle, it is slightly more adaptable and descriptive of real science than a once-through method. The cycle version is common in science education for older students or in higher education due to its slightly increased complexity and is generally seen as the lesser of two evils. My survey of UPS students supports this pattern–the majority of students who responded "cycle" when asked whether they were taught the scientific method as a cycle or a linear progression were STEM majors (see Figure 4). Since Khan academy has such a huge audience both in and outside of public schools, this is a great example of a typical presentation of the scientific method in science media.

Another popular video series, *Bill Nye the Science Guy,* is an example of the more entertainment-focused form of science media--every episode is a whirlwind of explosions, special effects, and excited children wearing lab coats. Bill Nye the Science Guy emphasizes repeatability, observation, and experiment as the three defining characteristics of science in his DIY science video.[84] While it is admirable that he doesn't directly discuss "the scientific method," he is still using a process-based approach to science education, which in this case does

[83] *The Scientific Method*. Films On Demand. Accessed September 17, 2021. https://fod.infobase.com/PortalPlaylists.aspx?wID=103122&contentID=N6IAzlugWw0&channel=KhanAcademy&chnID=55.

[84] bill nye video

closely resemble “the scientific method.” *Bill Nye the Science Guy* is an example of how focusing on practices and methods without using the term the scientific method does not always result in a picture of scientific thinking that is significantly different to the scientific method.

One of Bill Nye’s key points in his ever-popular videos is that his version of the scientific process, involving experimentation, repetition, and falsifiability, is what makes science trustworthy. Bill Nye’s approach to scientific authority reinforces the idea of method and process as the source of science’s authority. Cowles argues that in the past, scientific thinking was almost indecipherable from everyday thinking, but that nowadays, the scientific method is often presented as a unique and special way of thinking that does not come naturally. While the scientific method is often used to justify the validity of scientific information, not all modern discourse presents it as unnatural. The idea of the scientific method as natural and human is particularly common in educational media designed to engage young learners. For example, Bill Nye the Science Guy enthusiastically claims in his DIY Science video that “science is something we do all the time, everywhere we go.”[85] In the modern world, science appears to be integrated with nearly everything we do, yet it still holds a unique position in our minds--scientific institutions and scientific knowledge are generally regarded as the most reliable sources of information. This idea is exemplified by Bill Nye’s videos, Khan Academy’s veneration of the scientific method, and textbooks’ use of the scientific method as the source of their own authority as educational texts.

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[85] ibid

Folk Theory and Myth:

Lastly, the scientific method may owe its enduring presence in science education to the "folk theory" of what scientific inquiry is and should be. According to Mark Windschitl, a professor of science teaching at UW, the idea of scientific inquiry itself can be viewed as a folk theory. A folk theory is an idea or definition that is shared and reproduced in social discourse and writing, but that has no real definition.[86] Anthropologist Roger Keesing defines them as the following:

> Folk models, as culturally constructed common sense, are not cognitive organizations but a set of operating strategies for using cultural knowledge in the world. They comprise sets of shortcuts, idealizations, and simplifying paradigms that work well together but do not have to all fit together without contradiction into global systems of coherent knowledge.[87]

Folk models or theories can be subconscious or conscious, but it is impossible to think through them fully without discovering their lack of a concrete meaning. Folk theories are similar to the idea of cultural myths, in that they are passed between individuals through discourse and practices without real evidence behind them.

Framing the scientific method as a folk theory helps explain why it is so difficult to remove from curricula and even more difficult to remove from the minds of educators, as Mark Windschitl demonstrates in his study of science teachers. Windschitl found that most of the teachers he studied still thought within the framework of the scientific method, even though all of them were taught of its many faults in their graduate education.[88] These teachers made

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[86] Mark Windschitl, "Folk Theories of 'Inquiry:' How Preservice Teachers Reproduce the Discourse and Practices of an Atheoretical Scientific Method," *Journal of Research in Science Teaching* 41, no. 5 (2004): 482., https://doi.org/10.1002/tea.20010.
[87] Roger M. Keesing, "Models,"folk" and "cultural": paradigms regained." Cultural models in language and thought (1987), 379.
[88] Ibid., 483.

observations like "there is a scientific method, but it is not linear."[89] This statement demonstrates an awareness of the limitations of a linear method, but shows a strong mental attachment to the idea of the one scientific method. In his study, Windschitl analyzed the ways various science teachers created their own independent scientific inquiries. He found that most of them, like many of their students, rarely or never connected the elements of method they used–hypothesis, testing, and data collection, to any existing scientific knowledge or theory.[90] One subject created an experiment studying the impacts of various fertilizers on plants, but never researched existing knowledge about the function of fertilizers. This lack of broader contextualization of scientific inquiry and learning is one of the main criticisms leveled against modern "process-based" science education.[91] Finding it present not only in students, but in teachers themselves is problematic. Since teachers often default to teaching in the ways they remember learning content as children, (despite pressure to avoid doing so from education experts) the folk theory of scientific inquiry is continually reproduced through education.

Folk theories are self-perpetuating and difficult to eradicate. The scientific method may be an easy and simple way to present science to children, but as we have seen, it very often survives into higher education and stays with many individuals for a lifetime. When everyone is exposed to the scientific method at a young age, it percolates into the social consciousness and is perpetuated through actions and conversations and spread by educators and curriculum designers without a second thought. Therefore, it is necessary to re-work school curricula in a way that

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[89] Ibid., 491.
[90] Windschitl, "Folk Theories of "inquiry," 502.
[91] Ibid.

specifically targets the myth of the scientific method to help students understand that there are actually many.

Conclusion:

The scientific method has become both a formula for the “right” way to solve problems and the ultimate source for the authority of science. Science is everywhere, and there has been a huge push in recent years to strengthen science education. This emphasis on STEM education has led to a plethora of educational science media which often replicates the rhetoric of the scientific method, focusing on exciting experiments and independent research to engage students, but ignoring the realities of scientific practice. Critically, the “practice-based” learning style popular in modern science curricula, such as the NGSS, encourages students to practice scientific inquiry in isolation, leaving them with no knowledge of the vast network of scientific knowledge that feeds into every new professional study. It is crucial that students understand the realities of science so that when they become adults, they are able to recognize good science for what it is, and are able to trust scientific institutions and peer-reviewed journals.

Scientists in every field use different methods and techniques to learn about the natural world–big data collection, computer modeling, research without experimentation (like the majority of the earth sciences, for example), and so much more. Almost no scientist would say they follow the scientific method, and many feel pressured to conform to it when publishing their research, for fear of being misunderstood or labeled unscientific. Scholars of science agree that there is no one scientific method, and historians of science know well that the revered scientists of history certainly did not follow the scientific method.

Despite attempts by many science curriculum designers to remove the scientific method from curricula, exemplified by the NGSS and other sources of science education, the scientific method remains embedded in US science education due to its historical and social power, stemming from the myth of the scientific method and the folk theory of scientific inquiry. Beginning with Dewey's *How to Think,* the scientific method has perfectly filled the need of textbook authors and science curriculum designers for a structured and simple definition of science. Today, the scientific method is intertwined with the identity of science itself. In modern society, science holds a unique and ultimate authority over truth, knowledge, and decision making. The continued teaching of the scientific method only hampers educators' goals to improve public science literacy, because such a drastic oversimplification of science can leave students with a skewed mental image of science in a world where science literacy is more crucial than ever.

Epilogue:

I chose to research the scientific method because it is central to so many people's understanding of science. At this moment in time, science is everywhere--in politics, business, education, and everyday life. Policy makers and educators push for stronger public science literacy, and governments rely on the input of scientists for crucial decisions (especially if you include economics). To function in today's society and to make informed decisions as a citizen, a basic level of scientific literacy or at least a certain level of trust in scientific institutions is necessary. Science holds a uniquely authoritative position in society not only because social myths strengthen and spread its influence, but also because it works. Practically, no other way of knowing has done nearly as much for improving the quality of human life. Yet as the world faces catastrophes like climate change and the COVID pandemic, huge percentages of the US and world populations continually deny scientific fact. These science skeptics present a real threat to the wellbeing of the planet and of humanity, and despite the desperate attempts of scientists to change their minds, they continue to reject scientific consensus. Why?

STEM education and the scientific method also tend to completely ignore the social sciences, which is a rich and rapidly growing area of science, and one that certainly deserves to be included in discussions of scientific thinking. Social scientists follow many of the same approaches that natural scientists do--they strive for objectivity, do experiments, analyze data using statistics, and innumerable other things.

There is a visible tension in the science education community between two theoretically compatible but very different goals: Are we educating students in science in order to encourage them to go into STEM fields and benefit our economy, or are we educating them in science to help them develop critical thinking skills and logical reasoning? Do we want them to grow up to make informed policy choices regardless of career, or do we want them to become engineers? I think that the contrast between these two goals for science education in the US tends to result in conflicting messages about the nature of science as well as oversimplifications of scientific practice, which may contribute to public distrust of science.

Many science “skeptics” tend to “do their own research.” Following this research, which often involves social media or untrustworthy news sites, they conclude that they should not trust scientific authorities and institutions. This common practice of science skeptics demonstrates a fascinating paradox of thinking. The people who “do their own research” must at some level believe that research is valuable and that one should carry out some form of research in order to make a justified conclusion. Despite this internalized belief, this “research” is inevitably ruled by confirmation bias. Placing so much value on research shows that these people do value scientific or critical thinking, perhaps unconsciously, enough to believe that research is important. At the same time, science skeptics choose to ignore peer-reviewed scientific studies and other sources of trustworthy scientific information in favor of their own biased ideas. How do people both value and reject scientific methods at the same time?

In his sociological analysis of the public opinion of science, Peter Achtenberg argues for the existence of a "science confidence gap," meaning that people trust scientific methods, but distrust scientific institutions.[92] He and his co-authors argue that among less educated groups, "anomie" results in a desire for control in their personal lives, so they trust scientific methods, but strongly distrust institutions. They initially hypothesize that among more educated groups who tend to be liberal, "reflexive-modern values" and cultural progressiveness cause individuals to distrust "traditional" or institutional ways of knowing while trusting scientific thinking.[93] However, their study provides evidence to the contrary, showing that more educated groups trust both scientific methods and institutions. The authors ultimately argue that the science confidence gap is primarily present among less educated groups. This analysis could help explain why some less educated people tend to idealize the scientific method while still ignoring the advice of scientific institutions like the CDC or the EPA. The strange conflict between trust in scientific practices and distrust in scientific institutions appears common in the US and could be a fascinating topic for future study.

[92] Peter Achterberg, Willem de Koster, and Jeroen van der Waal, "A Science Confidence Gap: Education, Trust in Scientific Methods, and Trust in Scientific Institutions in the United States, 2014," *Public Understanding of Science* 26, no. 6 (August 1, 2017): 704–20, https://doi.org/10.1177/0963662515617367.
[93] Ibid.

Appendix:

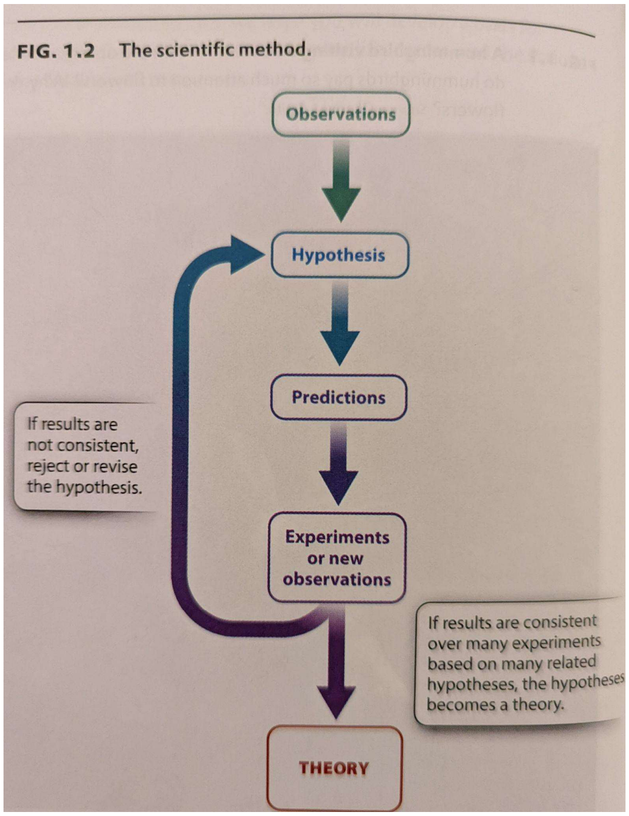

Figure 1. The linear scientific method.

From: Morris, James R., Daniel L. Hartl, Andrew H. Knoll, Robert Lue, Melissa Michael, Andrew Berry, Andrew A. Biewener, Brian B. Farrell, and Noel Michele Holbrook. *Biology: How life works*, 2nd ed. New York, NY: WH Freeman, 2016.

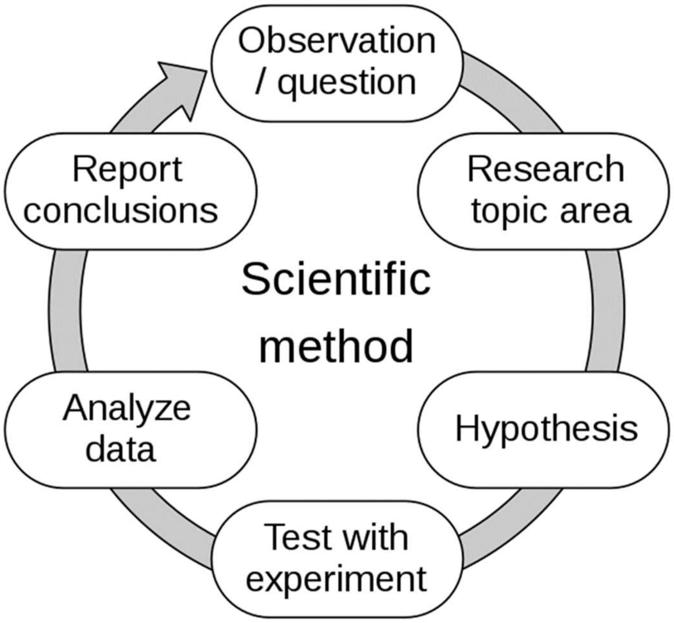

Figure 2. The cyclical scientific method.

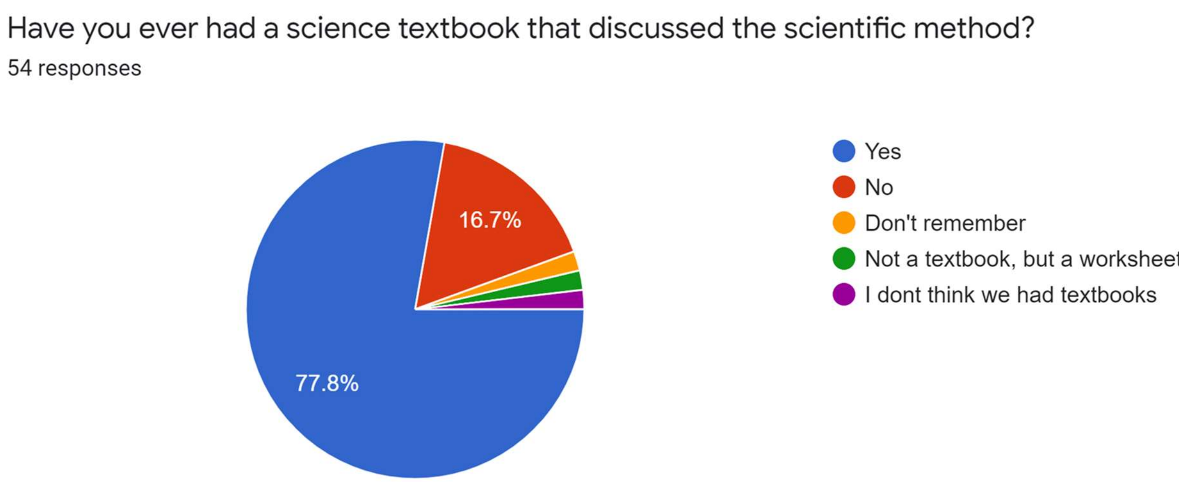

Figure 3. My survey data on textbooks.

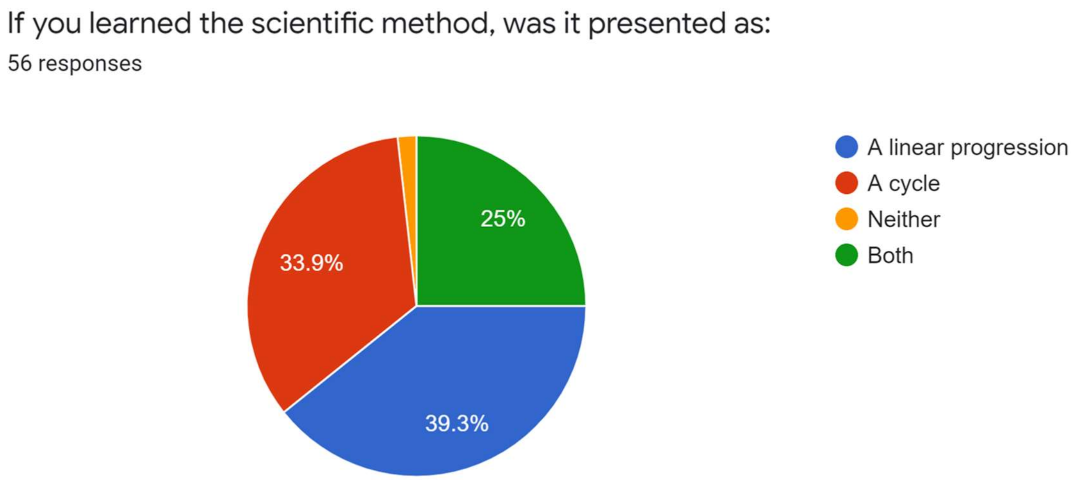

Figure 4. My survey data.

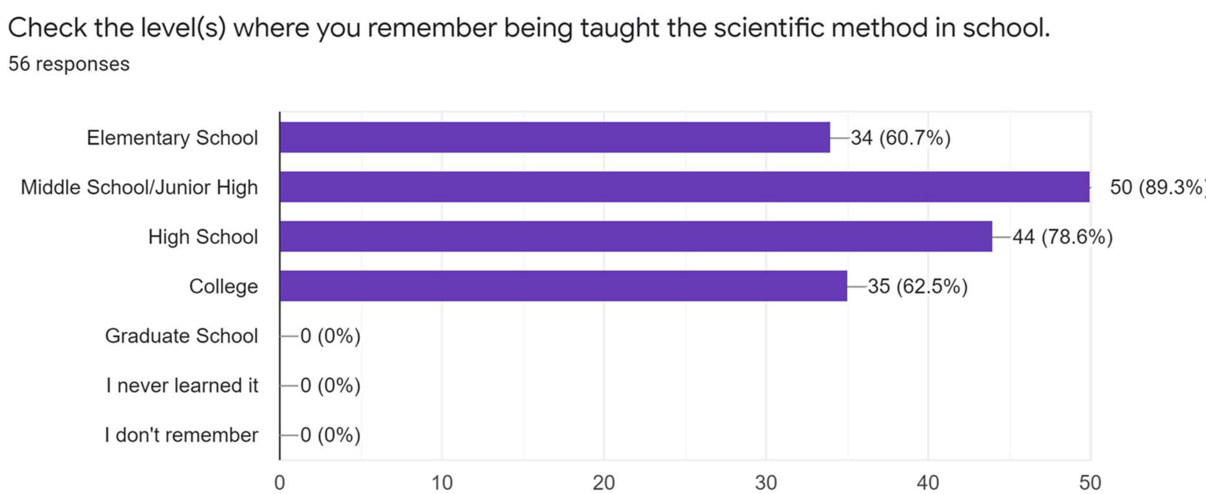

Figure 5. Survey Results.