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Knowledge about the nature of science increases public acceptance of science regardless of identity factors

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Abstract
While people's views about science are related to identity factors (e.g. political orientation) and to knowledge of scientific theories, knowledge about how science works in general also plays an important role. To test this claim, we administered two detailed assessments about the practices of science to a demographically representative sample of the US public ($N = 1500$), along with questions about the acceptance of evolution, climate change, and vaccines. Participants' political and religious views predicted their acceptance of scientific claims, as in prior work. But a greater knowledge of the nature of science and a more mature view of how to mitigate scientific disagreements each related positively to acceptance. Importantly, the positive effect of scientific thinking on acceptance held regardless of participants' political ideology or religiosity. Increased attention to developing people's knowledge of how science works could thus help to combat resistance to scientific claims across the political and religious spectrum.

Keywords
climate change, epistemological style, evolution, nature of science, philosophy of science, public understanding of science

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Some scientific claims are controversial among members of the public, especially in the United States. For example, despite overwhelming scientific consensus that evolutionary theory provides the best explanation for the origin and development of species, at least a quarter of the US public rejects this explanation (Smith and Son, 2013; Weisberg et al., 2018). In addition, there is a 37-point gap between members of the US public and members of the scientific community in terms of their acceptance of anthropogenic climate change (Pew Research Center, 2015). The same pattern can be seen with respect to vaccine safety (Pew Research Center, 2015; Villa, 2019).

Public resistance to well-established scientific claims is troubling not simply from an epistemic point of view; vaccine non-compliance, for example, has resulted in many deaths, and failure to acknowledge climate change can lead to similarly dire results. The recent (lack of) response to COVID-19 from members of the public and political leaders also underscores the ways in which science denial can have deadly consequences. It is thus imperative to identify the reasons behind people's resistance to science and to uncover effective ways to combat it.

1. Sources of resistance

People's opposition to science is often associated with identity factors, like political affiliation or religious identity (McPhetres and Zuckerman, 2018; Rutjens et al., 2018). For example, individuals who are more politically conservative and more religious tend to reject evolution at higher rates than average (Swift, 2017; Weisberg et al., 2018). Similarly, political conservatives are more likely to deny climate change (Brenan and Saad, 2018). Vaccine safety denial is similarly tied to identity factors, though these deniers hold extreme views at both ends of the political (Baumgaertner et al., 2018; Berezow and Campbell, 2012) and religious (Kennedy, 2017) spectrums.

These links between identity factors and science acceptance may occur because people's responses to survey questions about scientific issues are subject to pressure from their group affiliations (e.g. Douglas and Wildavsky, 1982; Kahan et al., 2011; Lewandowsky et al., 2013). For example, individuals who are more religious know that religion is seen as conflicting with evolution. So they may report that they do not accept evolution when asked, regardless of their personal views, because this response conforms to the views of their religious community. If people are sensitive *only* to the norms of their community when deciding what they should believe, then their knowledge about science plays little role, if any. In support of this argument, some previous work has found that knowledge of evolutionary theory does not relate to acceptance of it (e.g. Bishop and Anderson, 1990; Lawson and Worsnop, 1992; Shtulman, 2006). Simply teaching people the science behind evolutionary theory, anthropogenic climate change, or vaccine safety, then, will not increase acceptance.

But there is a reason to question this skeptical conclusion. Prior work has found positive correlations between individuals' knowledge of particular scientific theories and their acceptance of these theories (McPhetres et al., 2019; Weisberg et al., 2018). Furthermore, some studies have demonstrated that teaching the mechanisms of climate change (Ranney and Clark, 2016) and evolution (Ingram and Nelson, 2006; Lawson and Weser, 1990; Shtulman and Calabi, 2013) can increase acceptance of these theories. So, people's knowledge about particular scientific theories, not just their identities, can matter to science acceptance.

However, much of this work has examined only how people's knowledge about a scientific theory affects their acceptance of that particular theory. An educational strategy based on these results would thus involve teaching each theory separately. While it would be beneficial for members of the public to gain this knowledge, this strategy might not be the most efficient way to combat resistance to science. After all, it is impossible to know what sort of science knowledge may be relevant in the future, as science denial related to the current pandemic has demonstrated.

2. Measuring people's knowledge about the nature of science

A more promising approach may thus be to focus on people's knowledge of general science facts and of the processes and practices of science, known as the Nature of Science (NoS). In general, people who have higher NoS knowledge may be in a better position to understand the connection between scientific practices and the generation of knowledge (Nelson et al., 2019; Thanukos and Scotchmoor, 2012) or the role that the scientific community plays (Slater et al., 2019). This knowledge may allow for more robust acceptance of the scientific consensus or greater trust in scientific claims.

Indeed, several prior studies have found such a connection: People who perform better on tests of general science knowledge and reasoning are overall more likely to accept scientific claims, such as those about climate change and evolution (Lombrozo et al., 2008; McPhetres and Zuckerman, 2018; Rutjens et al., 2018; Weisberg et al., 2018). This connection presents a potentially fruitful avenue for intervention: Imparting a broad scientific knowledge base could potentially lead to greater acceptance of a variety of scientific claims without needing to address each of those claims directly. Furthermore, teaching about science in general may not encounter the kind of reflexive resistance that teaching directly about a specific controversial claim would.

But this connection between NoS knowledge and acceptance of scientific claims is more complex than it first appears. For example, the Ordinary Science Intelligence Scale (OSI) (Kahan, 2017) is a commonly used measure of NoS. It includes a subsample of basic science knowledge questions (e.g. electrons are smaller than atoms) drawn from the National Science Foundation (NSF) Science and Engineering Indicators (National Science Board, 2016). The OSI additionally includes measures of numeracy (e.g. how to express numerically a 1% chance of winning a prize if 1000 people enter a lottery), and measures of cognitive reflection (Frederick, 2005). While those who score highly on the OSI tend to accept climate change, in line with the work reviewed above, those who are additionally politically conservative are *less* likely to accept it (Kahan, 2015; Kahan et al., 2012). That is, greater knowledge about aspects of science actually corresponds to greater polarization in people's views (see also Drummond and Fischhoff, 2017; Hamilton, 2011).

Why might this be the case? While greater NoS knowledge may simply lead to greater polarization overall, it is important to note that some extant measures of NoS only ask people about scientific facts, hence may not capture the most probative aspects of NoS. For example, prior work has sometimes used questions about people's knowledge of scientific facts from the General Social Survey (e.g. True or false: More than half of human genes are identical to those of mice). While people should know these important science facts, they are simply facts, which one could memorize without really understanding. This could explain why greater knowledge of such facts does not always lead to better acceptance of scientific claims.

Other measures, including the OSI, do present questions that gauge people's knowledge of the methods of science (e.g. the need for a control group) or people's general thinking skills (e.g. general numeracy). But these measures do not tend to capture people's knowledge of how science generates knowledge or how scientists carry out their work. We hypothesize that those aspects of NoS are particularly important predictors of acceptance of scientific claims, since knowledge about the way in which science works may be necessary to making productive connections between scientific claims and the process of generating and validating those claims. Conversely, individuals who have poor knowledge about how science works (e.g. that there is only a single scientific method that must be followed rigidly, like a recipe) may thereby fail to know that scientific theories are reliable, valid, and supported by multiple converging lines of evidence. This hypothesis about the connection between knowledge about the processes and practices of science and acceptance of scientific claims has so far not been fully tested on a demographically representative sample in the

United States. This study aims to fill this gap. Specifically, we test whether greater knowledge about the aspects of the nature of science (NoS) described earlier could benefit people's acceptance of several publicly controversial scientific claims (evolution, anthropogenic climate change, and vaccine safety), regardless of their political or religious views.

Furthermore, and crucially, none of this prior work has directly examined how people think about scientific disagreements and their style of resolving such disagreements. Given that public discourse about scientific topics is often framed as debates between opposing sides, gaining an understanding of how members of public conceptualize these debates is vital. Specifically, individuals who see the debates as being completely black and white—one side must be incorrect if the other side is correct—may fail to accept scientific claims that seem controversial because they lack knowledge about how such claims can be both well-supported and defeasible, or about how different interpretations of evidence could possibly be valid.

This study addresses these issues by using two new measures of people's knowledge about these aspects of the NoS. One presents a series of 20 statements (e.g. "The process of science is nonlinear; each step can lead to many possible next steps.") for which participants rate their agreement. These statements all focus on some aspect of how science is practiced or how theories are developed, rather than on knowledge of particular scientific facts or general thinking abilities.

Our second measure gauges participants' epistemological styles. We present a brief vignette about a scientific disagreement, in which two groups of scientists investigated developmental deformities in a population of frogs (adapted from Barzilai and Weinstock, 2015). Some scientists had evidence that these deformities were caused by cysts in the leg area, while other scientists had evidence that these deformities were caused by chemicals in the water. Crucially, we do not ask our participants to judge which group was correct. Instead, we ask what it would take to decide which group was correct.

We do so by presenting four questions about this disagreement (e.g. "Can one know for certain what happened to the frogs?"). For each question, participants are asked to rate their level of agreement with three possible answers: "Yes. If the topic were to be investigated further, one could know for certain," "No. Even if the topic were investigated further, one could never know for certain because it is not possible to observe what really happened," and "Maybe. If the topic were to be investigated further, one could not be completely certain, but one could make a reasonable estimate." Participants rate their degree of agreement with each of these answers independently, allowing us to determine how much each participant's views align with each type of claim.

These three answers are designed to capture different epistemic styles (Kuhn et al., 2000, 2008). The first is *absolutism*, the idea that knowledge is objectively true and can be straightforwardly obtained from observation of the world. The second is *multiplism* (or *relativism*), the idea that knowledge is subjective because it is generated by human minds, hence any scientific view is just as valid as any other. The third is *evaluativism*, the idea that any body of scientific knowledge has degrees of certainty, hence scientific claims must undergo a continual process of evaluation in light of other knowledge and theories. Prior work has found this third idea is the most mature and is related to better performance on reasoning tasks for both adults and children (Kuhn et al., 2008; Thomm et al., 2017; Walker et al., 2012).

To our knowledge, these are the most nuanced measures of scientific thinking that have been presented to a representative sample of the US public, allowing us to fully explore the possibility that a general knowledge of how science works might provide an avenue toward reducing public rejection of well-supported scientific claims. It is important to note that, in contrast to prior work in this area, these two new measures do not test individuals' knowledge of any particular scientific theory or claim, or of any discrete facts. Rather, these measures examine higher order knowledge about how science works and how scientists should resolve disputes. As such, this study provides a first window into how knowledge of the processes and practices of science could mitigate identity-based resistance to specific scientific claims, regardless of one's knowledge about the science underlying the claims themselves.

Based on prior work, we predict that more politically conservative participants and more religious participants will tend to reject publicly controversial scientific claims. We additionally predict that both of our new measures of the NoS will be related to acceptance of scientific theories. Specifically, participants who have a better knowledge of the nature of theories and participants who have a more evaluativist style will be more likely to accept these theories. Finally, and most importantly, we predict that the relationships between politics and acceptance and between religion and acceptance will be moderated by participants' NoS knowledge and by their epistemological styles. Participants' knowledge about how science is practiced should provide protection against the effects of their ideology, making them *less* polarized in their views about scientific claims.

3. Methods

We pre-registered our hypotheses with respect to evolutionary theory (https://osf.io/y6amz); parenthetical numbering throughout the article refers to the measures, hypotheses, and analyses registered in that document. We consider our investigations with respect to climate change and vaccines exploratory.[1]

Participants

We contracted with YouGov, a survey firm, to recruit a sample of 1500 participants. This sample size represents the maximum number of participants YouGov could provide to us based on our available funding. The final sample included 811 women (54%) and 689 men (46%). Participants' average age was 50 years (SD = 16.4 years, range = 18–92 years).

YouGov originally administered our survey to 1611 participants drawn from their standing panels. Then, blind to our hypotheses, they selected our 1500 final participants by matching cases to a sampling frame on the variables of gender, age, race, education, political party identification, political ideology, and political interest. This sampling frame was constructed from the 2010 American Community Survey, the November 2010 Current Population Survey, and the 2007 Pew Religious Life Survey.

Measures

Participants completed 13 measures (pre-registration section 11). In this article, we focus on the following five: evolution acceptance (11.11), climate change acceptance (11.5), vaccine acceptance (11.7), knowledge of the NoS (11.1), and epistemic thinking style (11.2). The remaining eight measures asked about participants' views on the consequences of accepting the theory of evolution, the conflict between science and religion, the appropriate expert (scientific, religious, or other) to consult about a set of questions, the reasons that they might accept a claim, the reasons that they might consider a particular claim to be true, whether they identify as a particular kind of person (e.g. a science person, an arts person), and knowledge of evolutionary theory. See the Supplemental materials or the pre-registration site (https://osf.io/y6amz) for the exact text of all questions. As some of these measures were drawn from prior work, we followed those studies' practices with respect to randomization or counterbalancing of questions and answer options within each block.

Evolution acceptance. This multiple-choice question asked participants to choose which of the following options best describes how they think animals and plants (n = 740) or human beings (n = 760) came to exist on earth: (a) they were created by God in more or less their current form (creationist), (b) they developed through natural processes, which were guided by God the entire time (theist), (c) they developed through natural processes, which were set up by God but continued on their own (deist), or (d) they developed entirely through natural processes (naturalist). These answer options appeared in this order for all participants, following previous surveys of evolution acceptance that also presented the choices as decreasing in their level of supernatural involvement (e.g. the Gallup poll). Although three of these four answer options explicitly reference God, we based the wording of this question on previous measures of public acceptance of evolution and on our own piloting, both of which found that a majority of participants assent to God having some involvement in the process of evolution.

Climate change acceptance. We presented three questions about climate change (based on wording used by the Pew Research Center). All participants first responded to the question, "From what you've read and heard, is there solid evidence that the average temperature on earth has been getting warmer over the past few decades?" This question had three answer choices: "Yes, there is solid evidence that the earth is getting warmer"; "No, there is no solid evidence that the earth is getting warmer"; and "Don't know."

Participants who responded "yes" to this first question were then asked to choose the primary cause of climate change from the following options: "Human activity such as burning fossil fuels"; "Natural patterns in the earth's environment"; and "Don't know." Participants who responded "no" to the first question were asked to choose whether we just do not know enough yet about whether the earth is getting warmer or whether the earth just is not getting warmer, or they could indicate that they did not know. For all three questions, the first two options were presented in a random order.

Vaccine acceptance. We presented participants with a single question asking whether childhood vaccines were safe. There were four answer options: "very safe," "somewhat safe," "not very safe," and "not safe at all." As with the evolution acceptance question, these options were always presented in the same order, since they have a natural logical progression.

Nature of science index. We presented participants with 20 statements about the practice of science and the nature of scientific theories (Hofer, 2000; Liang et al., 2006; Lombrozo et al., 2008; Schommer, 1990).[2] For example, "The same hypothesis or theory is often tested in many different ways" and "Scientific theories are just scientists' guesses" (reverse-scored). For each statement, participants rated their level of agreement on a five-point scale: strongly disagree, disagree, unsure, agree, and strongly agree. The order of the 20 statements was randomized between participants.

Epistemic thinking style. This measure (based on Barzilai and Weinstock, 2015) first presented participants with a description of two theories about the causes of deformities in a population of frogs. This description was followed by four general questions about the nature of knowledge and how knowledge should be justified (e.g. "Must there be only one true explanation about the deformed frogs?"). These four questions were presented in a random order for each participant.

Each of these four questions had three possible answers, and these answers each reflected one of the three epistemological styles: absolutism, multiplism, and evaluativism. Participants used a scale from 1 ("very much disagree") to 10 ("very much agree") to rate their agreement with each statement. As in Barzilai and Weinstock (2015), these three statements were presented in a random order for each participant, and each statement was presented on a separate page in order to encourage participants to respond independently to each.

Procedure

Participants completed the survey online. Each of the 12 measures appeared as its own block in the survey. These blocks were presented in a random order except for the block about evolution acceptance, which always appeared last. This was done so as not to bias responses to our set of questions about evolution knowledge, which was a focus of our pre-registered analyses.

Questions about demographic factors (e.g. age, gender, political orientation) were presented on their own in a separate testing session before participants engaged in this survey. Responses from that session were used to construct a demographically representative sample, as noted earlier.

4. Results

Coding and descriptive statistics

Evolution acceptance. We first tested whether there were differences in responses to the "humans" and "plants and animals" versions of this question. We found overall differences in the distribution of responses among our four acceptance categories ($\chi^2(3) = 20.09$, $p < .001$). Specifically, the "humans" wording of the question received significantly more creationist responses than the "plants and animals" version (36.6% vs 26.4%; exact proportions test $p < .001$), significantly fewer deistic responses (17.4% vs 22.6%; exact proportions test $p < .001$), and marginally fewer naturalistic responses (30.9% vs 35.7%; exact proportions test $p = .057$). This aligns with other work showing that different versions of an acceptance question can yield different responses, particularly when comparing humans to other living things (Maitland et al., 2014; Miller et al., 2006). Given that participants responded generally similarly to the two versions of the question, and for ease of interpretation, we combined their responses into a single acceptance measure for our main analyses.

We found that 31.5% of participants agreed with the creationist option, 15.3% of participants agreed with the theist option, 20.0% of participants agreed with the deist option, and 33.3% of participants agreed with the naturalistic option.

For our main regression analyses, we split the four response options to this question into two categories: "created by God" and "guided by God" were coded as "leans creationist" (0) and "set up by God" and "natural processes" were coded as "leans evolutionist" (1). We pre-registered the analysis using this coding strategy because these pairs of categories tended to cohere and because the binary outcome variable is easier to interpret than the relational outcomes. Overall, 53.3% of our participants were categorized as leaning evolutionist.

Climate change acceptance. We used responses to the three climate change questions to construct a scale of responses (1–7), with higher numbers indicating closer agreement to the scientific consensus of anthropogenic climate change. Participants who responded "yes" to the first question (i.e. there is solid evidence that the Earth is getting warmer) and then attributed that fact to human activity were assigned the highest score (7) since this matches the scientific consensus. Participants who responded "yes" to the first question and then attributed that fact to natural patterns were assigned a score of 6. Participants who responded "yes" to the first question but then said they did not know why this was happened were assigned a score of 5. Participants who responded "don't know" to the first question were coded as 4. Participants who responded "no" to the first question (i.e. there is no solid evidence that the Earth is getting warmer) but then said they did not know why were assigned a score of 3. Participants who responded "no" to the first question and then said that we just do not know enough yet were assigned a score of 2. Participants who responded "no" to the first question and then said that the Earth just is not getting warmer were assigned a score of 1.

The average overall score on this scale was 5.1 (*SD* = 2.1), significantly higher than the midpoint of the scale (4; $t(1499) = 20.6, p < .001$). We found that 62.5% of our population said that they accepted climate change, indicating that a majority of US citizens agree with the scientific consensus on this issue. These numbers are generally in line with reports from other polls: Gallup, for example finds that 66% of the population accepts that climate change is happening (Brenan and Saad, 2018; see also Leiserowitz et al., 2010). In addition, 45.9% of our population agreed that climate change is caused by human activity.

As with evolution acceptance, we created a binary acceptance variable to use in our main analyses. Participants who responded "yes" to the first question (i.e. there is solid evidence that the Earth is getting warmer, in agreement with the scientific consensus) were assigned a score of 1. All other participants were assigned a score of 0.

Vaccine acceptance. We coded participants' responses so that higher scores were assigned to answers that more closely reflected the scientific consensus (as we did with climate change). Responses of "not safe at all" were coded 1, "not very safe" were coded 2, "somewhat safe" were coded 3, and "very safe" were coded 4. One participant who skipped this question was removed from analyses that used this scale.

Overall, 88.9% of our participants accepted the safety of vaccines, with 53.1% of all participants saying that vaccines were very safe. These numbers align well with a 2016 Pew poll, in which 88% of US respondents judged vaccines to be safe (Villa, 2019). The average score on our acceptance scale for vaccines was 3.38 (*SD* = 0.79), which is significantly higher than the midpoint of the scale (2.5; $t(1498) = 42.99, p < .001$).

We again created a binary variable for analysis, with scores of 1 and 2 reflecting overall nonacceptance (coded 0) and scores of 3 and 4 reflecting overall acceptance (coded 1).

Nature of science index. We converted participants' responses to the 20 items into a scale from 1 (strongly disagree) to 5 (strongly agree). Eight of the items were reverse coded. Each participant's responses to these 20 items were averaged into a single score, with higher numbers reflecting a greater knowledge about NoS. We examined the unity of this index using the nFactors package in R. An analysis of eigenvalues, a parallel analysis, and an optimal coordinates analysis suggested a three-factor solution (see Table 1), whereas the acceleration factor suggested a one factor solution. Next, we conducted an exploratory factor analysis specifying three factors using the psych package in R. Examining the factor loadings (see Table 1) suggests that the factors correspond to (1) a recognition that science is an ongoing and potentially nonlinear process (11 items), (2) (not) viewing science as a set, stable method (seven items), and (3) (not) dismissing science as mere guesswork (two items).

It is worth noting that although three factors were suggested, the factors appeared to break down based on whether the items were reverse coded. Given this and the fact that internal consistency for the entire index was strong (Cronbach's alpha = .84), we chose to retain all items in for analyses. Average score on this index was 3.73 (*SD* = 0.45). Although this is significantly above the midpoint of the index (2.5; $t(1499) = 106.66, p < .001$), the distribution of responses is roughly normal.

Epistemic thinking style. This measure asked participants their level of agreement with 12 statements, four for each of the three epistemic thinking styles (absolutist, multiplist, and evaluativist). Each participant's responses to the four statements reflecting each style was averaged together, creating three scores per participant. Following the study on which this measure was based (Barzilai and Weinstock, 2015), these averages ranged from 1 to 10, with higher numbers reflecting a greater degree of agreement with each thinking style. One participant failed to respond to one of

Table 1. Factor loadings for the Nature of Science index. Loadings below 0.30 are not displayed.

Item	Statement	Factor 1	Factor 2	Factor 3
NOS3	To be accepted, scientific theories must be supported by much evidence.	0.59		
NOS7	The same hypothesis or theory is often tested in many different ways.	0.67		
NOS9	The process of science is nonlinear; each step can lead to many possible next steps.	0.66		
NOS11	Scientific knowledge is built through a complex process that relies, in part, on observations of nature.	0.63		
NOS13	Scientific theories are subject to ongoing testing and revision.	0.72		
NOS15	Scientific investigations usually lead to additional questions for further investigation.	0.74		
NOS17	An important aim of scientific testing is to figure out which explanation for a phenomenon is most likely to be correct.	0.58		
NOS19	The scientific community is essential to the process and progress of science.	0.56		
DEF2	Answers to questions can change as experts gather more information.	0.71		
AUTH1	It is good to question the ideas presented by others.	0.66		
NOS5	Accepted scientific theories are well-supported explanations for a broad set of natural phenomena.	0.42		0.41
NOS1.rc	Once a scientific theory has been established, it is never changed.		0.67	
NOS8.rc	Scientific investigations always require laboratory experiments.		0.52	
NOS14.rc	Scientific theories based on accurate experimentation will not be changed.		0.57	
DEF4.rc	All researchers always come up with the same answer to a question.		0.64	
DEF1	Scientists can ultimately get to the truth.		−0.38	0.39
NOS10.rc	Scientific research is always conducted in the following order: (1) Observation, (2) Hypothesis, (3) Experiment, (4) Conclusion	−0.32	0.38	
NOS18.rc	Data collected for one experiment can only be used for that experiment.		0.43	
NOS2.rc	Scientific theories are just scientists' guesses.			0.74
NOS4.rc	New hypotheses are basically wild guesses; scientists just dream them up.			0.67
	Eigenvalues	6.11	2.68	1.65

the evaluativism items, so this missing value was filled in with the mean of the sample for that question before constructing this participant's evaluativism summary score.

Overall scores on the absolutism scale ($M = 6.55$, $SD = 1.47$) and on the evaluativism scale ($M = 7.01$, $SD = 1.45$) were significantly above the midpoint of the scale (5.5; $t(1499) = 27.55$, $p < .001$ and $t(1499) = 40.17$, $p < .001$, respectively). Scores on the multiplism scale ($M = 4.81$, $SD = 1.80$) were significantly below the midpoint ($t(1499) = -14.78$, $p < .001$). Cronbach's

Table 2. Zero-order correlations among all variables.

	1	2	3	4	5	6	7	8
1. Evolution acceptance	X							
2. Climate change acceptance	0.27**	X						
3. Vaccine acceptance	0.11**	0.21**	X					
4. NoS index	0.33**	0.33**	0.30**	X				
5. Absolutism	−0.01	0.13**	0.09**	0.06*	X			
6. Multiplism	−0.28**	−0.16**	−0.09**	−0.49**	0.08**	X		
7. Evaluativism	0.12**	0.19**	0.20**	0.29**	0.41**	0.19**	X	
8. Political orientation	−0.42**	−0.54**	−0.19**	−0.32**	−0.08**	0.24**	−0.17**	X
9. Religiosity	−0.63**	−0.26**	−0.08**	−0.23**	−0.02	0.23**	−0.06*	0.42**

*$p < .05$; **$p < .01$.

alpha for the absolutism scale was .52, for the multiplism scale was .66, and for the evaluativism scale was .62. Although these alpha values are somewhat low, we chose to use these scales as they were presented in order to remain consistent with prior work using this measure.

Political orientation. Participants were asked to rate their ideology on a five-point scale, which we scored from 1 ("very liberal") to 5 ("very conservative"). There were 162 participants who responded "not sure"; their data were removed from analyses involving this scale. We found that 13.1% of our participants reported being very liberal, 16.7% liberal, 33.2% moderate, 23.5% conservative, and 13.5% very conservative. The average overall score on this scale was 3.08 (SD = 1.21), significantly higher (i.e. more conservative) than the midpoint of the scale ($t(1337) = 2.29$, $p = .02$).

For data visualization (although not for analyses), we transformed this into a three-point scale by labeling participants who responded "very liberal" or "liberal" as *liberal* and participants who responded "conservative" or "very conservative" as *conservative*.

Religiosity. Participants responded to three questions from the Pew Religious Life battery, which asked about their frequency of attendance at religious services, the importance of religion in their lives, and their frequency of prayer. Responses to these three items were made on different scales. To combine them into a single scale, we first normalized the scale for each item. Then we averaged these scores together and normalized this composite scale, which we used in our analyses. Because we normalized the scale, the average was 0 and SD was 1.

For data visualization only, we split this scale into three groups, with participants responding more than one SD above M being labeled "highly religious" (25% of the sample), participants responding between one SD above and below M being labeled "average religious" (50% of the sample), and participants responding more than one SD below M being labeled "low religious" (25% of the sample).

Table 2 provides a correlation matrix for all variables.

Acceptance of evolutionary theory (pre-registered analyses)

Individual predictors. We examined the likelihood that participants leaned evolutionist conditional on their political ideology, religiosity, knowledge of the NoS, and their epistemic thinking styles (absolutism, multiplism, and evaluativism scores). Separate logistic regression analyses were conducted to characterize the relationship between each variable and evolution acceptance (see sections 4.1.6, 4.2, and 17.2 in our pre-registration).

As predicted, conservative political ideology ($b = -0.66$, $p < .001$; hypothesis 4.2.2.3) and greater religiosity ($b = -1.39$, $p < .001$; hypothesis 4.2.2.2) were associated with a decreasing likelihood of leaning evolutionist. Greater NoS knowledge was associated with an increasing likelihood of leaning evolutionist ($b = 1.61$, $p < .001$; hypothesis 4.2.1.4). Increasing evaluativism predicted a greater likelihood of leaning evolutionist ($b = 0.14$, $p < .001$; hypothesis 4.2.1.8), whereas increasing multiplism predicted a lower likelihood of leaning evolutionist ($b = -0.33$, $p < .001$; hypothesis 4.2.1.7). Contrary to our predictions, absolutism was unrelated to whether participants leaned evolutionist ($b = -0.01$, $p = .774$; hypothesis 4.2.1.7).

Conditional effects. We next examined whether the relations between leaning evolutionist and NoS knowledge, and between leaning evolutionist and having an evaluativist thinking style, were conditional on the identity variables (political orientation and religiosity) (hypothesis 4.1.7). We conducted logistic regression analyses predicting the degree of leaning evolutionist from our two measures of science epistemology and from the two identity variables, including the interaction terms. Here, following our pre-registration (section 17.1), we examined relations with political ideology and religiosity separately.

In terms of political ideology, the probability of leaning evolutionist increased with increasing NoS knowledge (odds ratio 38.7) and with increasing evaluativist thinking (odds ratio 1.07) for each level of political orientation (Figure 1, top panels). In addition, we found that the relationship between leaning evolutionist and NoS knowledge was conditional on political ideology ($b = -0.67$, $p < .001$), such that greater political conservatism was associated with a weaker influence of NoS knowledge on leaning evolutionist. However, the relationship between leaning evolutionist and evaluativism was not conditional on political ideology ($b = 0.003$, $p = .929$): Increasing one's commitment to an evaluativist thinking style increased the likelihood of leaning evolutionist equally across the political spectrum.

As with political ideology, the probability of leaning evolutionist increased with increasing NoS knowledge (odds ratio 4.42) and with increasing evaluativist thinking (odds ratio 1.18) for each level of religiosity (Figure 1, bottom panels). The relationship between leaning evolutionist and NoS knowledge was conditional on religiosity ($b = -0.50$, $p = .005$); the predicted probability of leaning evolutionist increased with increasing NoS knowledge of the NoS even for those who scored in the top 25% of our measure of religiosity, but their increase was less steep. The relationship between leaning evolutionist and evaluativism was also conditional on religiosity ($b = -0.12$, $p = .013$) with the probability of leaning evolutionist increasing with greater evaluativist thinking only for those with middle to lower religiosity scores.

Acceptance of climate change (exploratory analyses)

Individual predictors. In parallel to our analyses of evolution acceptance, we conducted separate logistic regression analyses predicting our binary climate change acceptance variable from the other variables individually. Because these analyses were not pre-registered, we used a Bonferroni correction to adjust our alpha level to .0083, which accounts for the six tests that we ran. We found that conservative political ideology ($b = -1.05$, $p < .001$) and greater religiosity ($b = -0.50$, $p < .001$) were significantly associated with a decreasing likelihood of accepting climate change. Greater knowledge of the NoS ($b = 1.82$, $p < .001$), increasing absolutism ($b = 0.21$, $p < .001$), and increasing evaluativism ($b = 0.31$, $p < .001$) predicted a greater likelihood of acceptance. Increasing multiplism predicted a lower likelihood of acceptance ($b = -0.18$, $p < .001$).

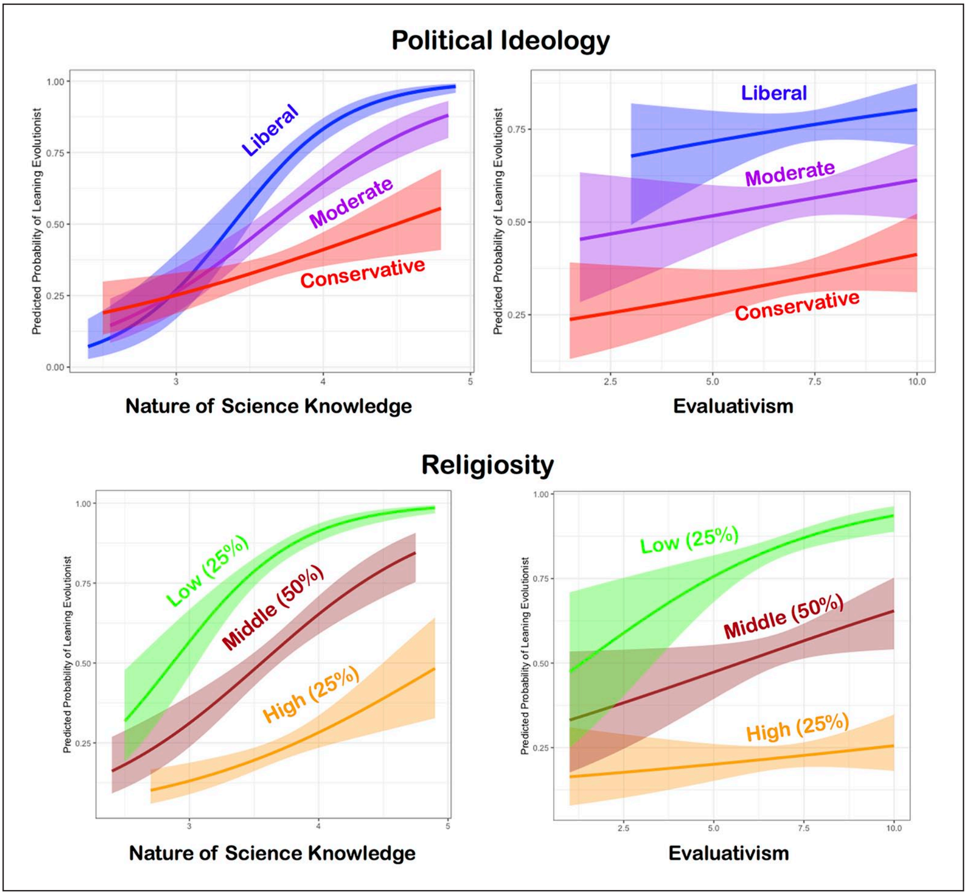

Figure 1. Relations between evolution acceptance, science epistemology measures, and demographic factors. Shaded areas represent 95% confidence intervals.

Conditional effects. As for evolution acceptance, increasing NoS knowledge (odds ratio 48.8) and increasing agreement with evaluativist statements (odds ratio 1.52) was associated with an increased likelihood of accepting climate change across all levels of political orientation. This pattern also held across all levels of religiosity (odds ratio 5.66 for NoS knowledge and 1.38 for evaluativism) (Figure 2). Again, we used a Bonferroni correction to adjust the alpha level to account for multiple comparisons across these four tests (new alpha = .0125).

We additionally found that the relationship between NoS knowledge and accepting climate change was conditional on political ideology ($b = -0.74$, $p < .001$), whereas the relationship between evaluativist thinking and accepting human-caused climate change was not ($b = -0.05$, $p = .26$). Likelihood of acceptance increased with increasing NoS knowledge and increasing evaluativist thinking style for each of the political leanings. This increase was sharper for liberals than for conservatives, but only for the NoS index.

The relationship between accepting climate change and NoS knowledge was also conditional on religiosity ($b = -0.64$, $p < .001$), but the relationship between accepting climate change and evaluativism was not ($b = -0.06$, $p = .12$). The predicted probability of accepting climate change increased with increasing NoS knowledge and with increasing evaluativist thinking, even for those

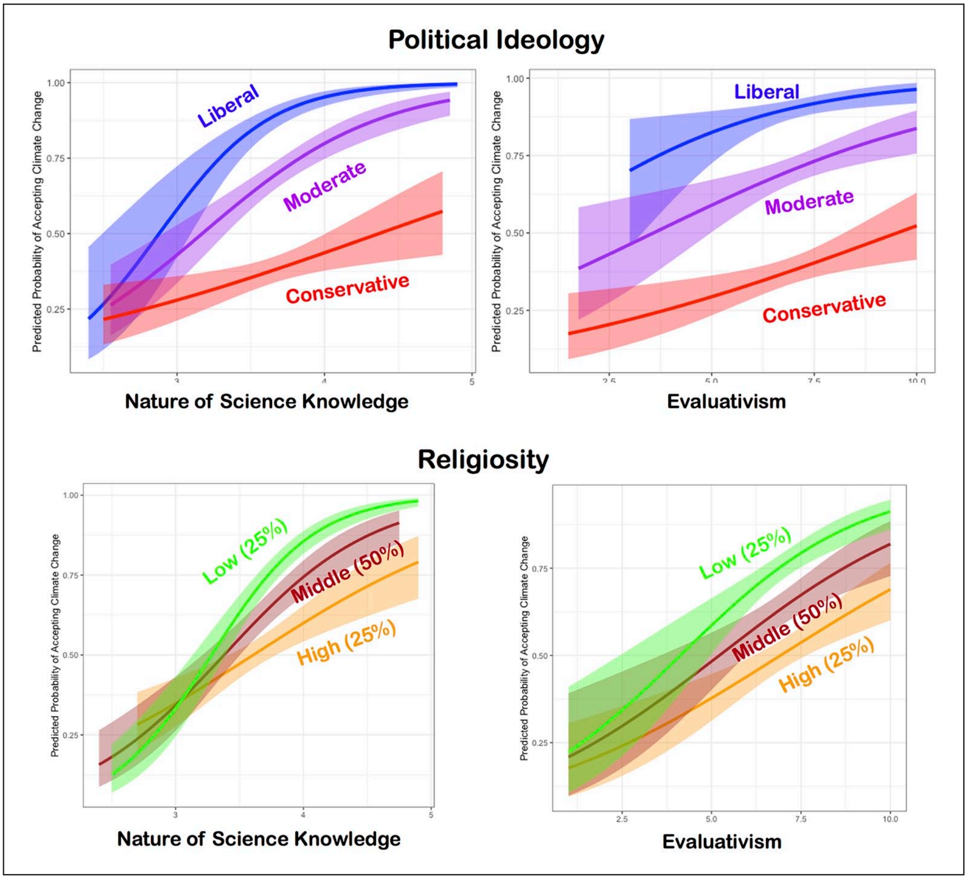

Figure 2. Relations between climate change acceptance, science epistemology measures, and demographic factors. Shaded areas represent 95% confidence intervals.

who scored in the top 25% of our measure of religiosity. This increase was sharper for low-religiosity individuals than for high-religiosity individuals, but only for the NoS index.

Acceptance of the safety of vaccines (exploratory analyses)

Individual predictors. With an adjusted alpha level of .0083, conservative political ideology ($b = -0.33$, $p < .001$) was significantly associated with a decreasing likelihood of accepting that vaccines are safe. Greater NoS knowledge ($b = 1.50$, $p < .001$) and increased evaluativism significantly predicted acceptance of vaccines' safety ($b = 0.32$, $p < .001$). Greater religiosity ($b = -0.08$, $p = .34$), absolutism ($b = 0.07$, $p = .19$), and multiplism ($b = -0.06$, $p = .21$) were not significant predictors.

Conditional effects. As in our climate change analyses, we adjusted our alpha level of .0125 to account for multiple comparisons. Both increasing NoS knowledge and increasing evaluativism were associated with increased probability of acceptance across the political and religious spectrum (Figure 3). The likelihood of accepting that vaccines are safe increased with increasing NoS

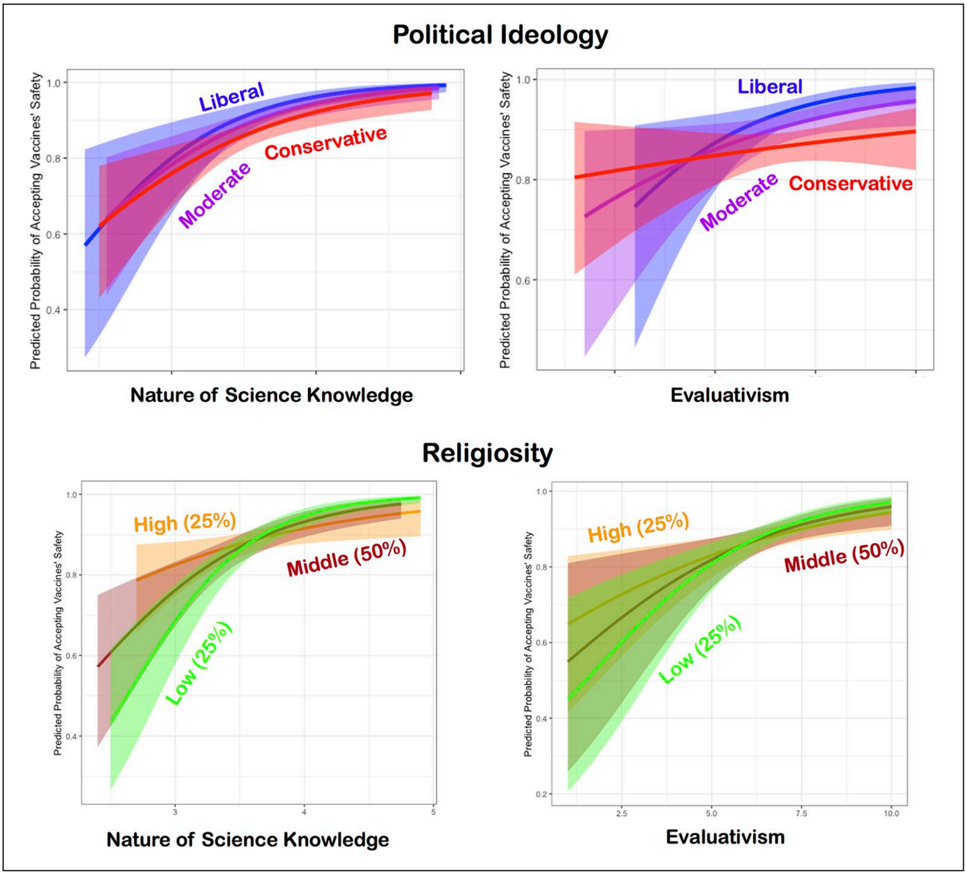

Figure 3. Relations between vaccine acceptance, science epistemology measures, and demographic factors. Shaded areas represent 95% confidence intervals.

knowledge (odds ratio 8.3), and this relationship did not differ across all levels of political ideology ($b = -0.19$, $p = .34$). The same was true for the relationship between vaccine acceptance and evaluativism (odds ratio 1.86), which also did not significantly differ based on political ideology ($b = -0.12, p = .035$).

In terms of religiosity, the relationship between vaccine acceptance and NoS knowledge was significantly conditional on religiosity ($b = -0.56, p = .007$). Although individuals at all levels of religiosity increased their likelihood of accepting vaccines' safety with increasing NoS knowledge (odds ratio 4.3), individuals of high religiosity experienced the increase in acceptance with increasing NoS knowledge at a less dramatic rate (see Figure 3, bottom panels). The relationship between vaccine acceptance and an evaluativist thinking style was not significantly conditional on religiosity ($b = -0.07, p = .18$); individuals across the religious spectrum were more likely to accept vaccines' safety with increasing evaluativism (odds ratio 1.39).

5. Discussion

Previous investigations of public acceptance of science have focused on identity factors, like political orientation, finding that such factors play a strong role in whether individuals accept or reject scientific claims (e.g. Lewandowsky et al., 2013; McPhetres and Zuckerman, 2018). Furthermore, although some prior work suggests greater knowledge of the NoS is related to greater acceptance (e.g. Weisberg et al., 2018), other studies find that greater NoS knowledge is associated with greater polarization (e.g. Kahan et al., 2012). This study focuses specifically on knowledge of the processes and practices of science and finds that this higher-order knowledge about science does relate to acceptance of specific scientific claims. Indeed, in many cases, this relationship was not attenuated by identity factors. This latter point is critical, as it suggests that it might be possible to increase one's knowledge of how science works and one's acceptance of scientific claims without interference from one's political orientation or religiosity. This work thus suggests possible avenues for developing effective interventions that could address the lack of public acceptance of well-confirmed scientific claims.

More specifically, using a representative sample of the US population, we found that people's responses to our NoS index significantly predicted their acceptance of evolution, climate change, and the safety of vaccines. Importantly, the likelihood of accepting the scientific consensus increased with increasing NoS knowledge across all political identity groups and all levels of religiosity. That is, as predicted, individuals with greater knowledge about aspects of modern scientific practice and the nature of scientific theories were more likely to agree with the scientific consensus on all three publicly controversial scientific claims.

We found the same pattern when examining people's epistemic thinking styles; higher degrees of evaluativism (the understanding that claims can have degrees of correctness and must be evaluated in the light of multiple sources of evidence) were positively related to acceptance of all three scientific claims. By contrast, multiplism was negatively related to acceptance of all three claims, indicating that a view of science as a collection of opinions does not provide a helpful basis for accepting the scientific consensus. Unexpectedly, absolutism was not related to acceptance of evolution, although it was positively related to acceptance of climate change and to acceptance of vaccines' efficacy. These results suggest that a view of science as having a single correct answer could assist people in agreeing with the scientific consensus. However, evolution may be too closely linked to identity factors to allow for this view to have a helpful influence. Importantly, however, increased commitment to evaluativism was consistently associated with increased acceptance across all levels of political conservatism and of religiosity, often with no attenuation from these identify factors.

Crucially, for no political ideology or level of religiosity was increasing NoS knowledge or increasing evaluativism related to decreased acceptance of science claims. This does not mean that political and religious worldviews had no influence on acceptance, however. We did find that the effects of knowledge on acceptance were weakened for members of the most highly conservative and the most highly religious groups; these individuals' views did not increase as much as those of liberal individuals or less-religious individuals as the knowledge factors increased, especially in the context of evolution and climate change. That is, political and religious identification still matter to the acceptance of scientific claims, and a greater knowledge of the NoS does not entirely remove their influence. Importantly, however, the identify factors never reversed the effect of the knowledge factors. These results point to the importance of a general knowledge about the epistemology of science to one's acceptance of scientific claims.

This conclusion, on its face, may seem to be in tension with earlier work in this area, which has found that individuals who were ideologically pre-disposed to reject a scientific finding were even less likely to accept that scientific finding when they had more science knowledge, at least for climate change (Drummond and Fischhoff, 2017; Kahan et al., 2012; Rutjens et al., 2018). But this difference can be explained by the differences in the measures of NoS used in these various studies. Kahan's work used the OSI scale, which includes questions about basic science facts, numeracy, and aspects of scientific methods; other work that has come to similar conclusions has examined only knowledge of science content (Drummond and Fischhoff, 2017; Rutjens et al., 2018). In contrast, our measures assess participants' knowledge of the processes and practices of science and their epistemological styles, which are different dimensions of people's thinking about science. By capturing these aspects of participants' knowledge, our new measures complement this prior work by demonstrating that individuals' knowledge of how science works is a strong predictor of science acceptance.

One obvious limitation to this study is that it is correlational; it is not possible to establish how these relations came about using the current data, and we are not able to make claims about the direction of causality. Individuals with a greater orientation toward scientific thinking may be more likely to accept science, or individuals who already accept scientific claims may be more likely to educate themselves about the workings of science, or there may be some other common cause. Future work should investigate this question through interventions that teach aspects of the NoS and then measure acceptance of particular science theories. Indeed, many current guidelines for science education emphasize imparting an understanding of how science works and a familiarity with scientific reasoning skills (e.g. NGSS Lead States, 2013), on the assumption that this will provide students with the tools for properly evaluating scientific claims. The current data provide preliminary evidence in favor of this conclusion. Future work should build on these results to uncover exactly how one's knowledge about the NoS may influence and be influenced by one's views about scientific claims.

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Supplemental material

Supplemental material for this article is available online.

Notes

1. These data were collected as part of a larger study on factors influencing public acceptance of evolutionary theory. The hypotheses and pre-registered analyses associated with that larger study are reported in full in the Supplemental materials; we choose not to report all of those measures and tests here in order to focus this article more sharply on the relations among identity factors, understanding of the process of science, and acceptance of science.
2. Our original version of the index, as reported in our pre-registration, had 23 items. We removed three of these items because they asked about participants' opinions (e.g. "When thinking about how the world works, I am more likely to accept the ideas of someone with firsthand experience than the ideas of researchers"). Because these items do not have an objectively correct answer, they cannot be coded in the same way as the rest of the items in the index. We filed a Transparent Changes document on OSF to report this deviation from our pre-registered analysis plan.

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