Individuals with greater science literacy and education have more polarized beliefs on controversial science topics

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Although Americans generally hold science in high regard and respect its findings, for some contested issues, such as the existence of anthropogenic climate change, public opinion is polarized along religious and political lines. We ask whether individuals with more general education and greater science knowledge, measured in terms of science education and science literacy, display more (or less) polarized beliefs on several such issues. We report secondary analyses of a nationally representative dataset (the General Social Survey), examining the predictors of beliefs regarding six potentially controversial issues. We find that beliefs are correlated with both political and religious identity for stem cell research, the Big Bang, and human evolution, and with political identity alone on climate change. Individuals with greater education, science education, and science literacy display more polarized beliefs on these issues. We find little evidence of political or religious polarization regarding nanotechnology and genetically modified foods. On all six topics, people who trust the scientific enterprise more are also more likely to accept its findings. We discuss the causal mechanisms that might underlie the correlation between education and identity-based polarization.

science literacy | polarization | science communication | science education | trust

Although Americans generally hold science in high regard and respect its findings, American public opinion on many contemporary science and technology issues is polarized along religious and political lines. On topics ranging from climate change to evolution, the stronger Americans' religious and political identities are, the more likely they are to espouse attitudes consistent with them. For example, individuals who self-identify as political conservatives and endorse free-market capitalism are less likely to believe in climate change and express concern about its impacts (1–9). Individuals who report stronger religious beliefs are less likely to support technologies that they view as interfering with divine creation, such as nanotechnology (10), or to accept the science of evolution, if they view it as contradicting the biblical account of creation (11).

In some cases, individuals can affirm their identity by rejecting the scientific consensus with few practical consequences. The Big Bang, as an example, has little role in everyday life. In other cases, though, actions guided by political or religious identity can be costly. Refusing to immunize children creates risk for them as well as for individuals who are medically unable to be vaccinated, such as the elderly or chronically ill; it has caused recent outbreaks of preventable diseases, such as measles and mumps (12). Rejecting the scientific consensus on evolution may lead parents to advocate for school curricula that omit key scientific concepts, adversely affecting science education and support for scientific research. Societies that ignore climate change contribute to global risks, including food insecurity, political instability, and environmental degradation (13).

We investigate whether people with greater science knowledge and education tend to express beliefs on controversial topics that are more, or less, polarized by religious and political identity. A meta-analysis found that individuals with greater science literacy are more likely to report positive attitudes toward science, although the effect size was small (14). That pattern has been invoked to support the deficit model of science communication: If people do not accept science, it is simply because they do not understand it; therefore, all they need are more facts (15, 16). Prior research on beliefs about controversial scientific issues has tested the hypothesis, consistent with the deficit model, that more educated individuals are more likely to hold beliefs consistent with the scientific consensus.

However, these studies have found that where partisan gaps exist in American public opinion, they are typically larger among individuals with more years of formal education. Beliefs on controversial issues typically display a funnel pattern, such that the gap between beliefs among political conservatives and liberals widens as education increases. For example, political conservatives are more likely to reject the scientific consensus on climate change if they have more education (1, 4, 9, 17). Studies looking at scores on science literacy tests, as reflections of science education, have found the same pattern: Conservatives with higher scores display less concern about climate change, while liberals with higher scores display more concern (5). The funnel pattern also holds for individuals' perceptions of their scientific knowledge (4, 18).

In addition to these studies, largely focused on climate change, the same funnel-shaped pattern has been found with Americans' beliefs about other contested scientific topics. For example, in a recent study, liberals reported greater trust in scientists as sources of information regarding vaccines and climate change, and this partisan gap widened with education (19). Another recent study found that conservatives with greater

Significance

Public opinion toward some science and technology issues is polarized along religious and political lines. We investigate whether people with more education and greater science knowledge tend to express beliefs that are more (or less) polarized. Using data from the nationally representative General Social Survey, we find that more knowledgeable individuals are more likely to express beliefs consistent with their religious or political identities for issues that have become polarized along those lines (e.g., stem cell research, human evolution), but not for issues that are controversial on other grounds (e.g., genetically modified foods). These patterns suggest that scientific knowledge may facilitate defending positions motivated by nonscientific concerns.

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science literacy were less likely to support funding science and using it in policy making (20).

Research in judgment and decision making has identified many ways in which individuals are biased information processors. Two classes of those processes could produce the observed funnel-shaped pattern. One class involves motivated reasoning, whereby individuals seek, evaluate, interpret, and recall information in ways that support their prior beliefs and commitments (21). Plausibly, better educated people are more adept at pursuing these strategies (22–24). That account would not, however, explain the increased polarization found with individuals who only perceive themselves to have greater scientific knowledge (4, 18). Perceived knowledge may not be related to actual knowledge, as found, for example, in one study focused on nanotechnology (25). Indeed, a second class of imperfect judgment processes involves miscalibration, whereby individuals' confidence in their knowledge is only weakly correlated with its actual extent, emerging as overconfidence when knowledge is limited (26–29). If more educated individuals are more confident in their beliefs in education-related domains, regardless of their actual knowledge (30), then they could have more extreme positions on polarized issues.

Here, we assess the generalizability of the finding that members of the American public with more education hold more polarized beliefs on contested scientific issues, based on secondary analyses of the nationally representative General Social Survey (GSS) (31). We seek to examine the conditions in which education is associated with greater partisan gaps in attitudes toward science and technology, and, thereby, contribute to a theoretical understanding of the mechanisms underpinning public reception of science and a practical understanding of public opinion regarding contemporary science and technology policy issues. We examine beliefs regarding six contested issues: the existence of human evolution and the Big Bang, willingness to eat genetically modified foods, the risks and benefits of nanotechnology, support for government funding of stem cell research, and concern about climate change. Our analyses ask (*i*) whether beliefs on these issues are related to GSS measures of political and religious identity and (*ii*) whether that polarization is stronger among more educated respondents. We use three GSS measures of education: a categorical measure of general educational attainment, a dichotomous measure of science educational attainment, and scores on a test of scientific literacy. For two issues, nanotechnology and climate change, we are also able to use GSS measures of topical scientific knowledge as an additional measure of education.

Finally, we examine the relationship between beliefs on these specific issues and general trust in the scientific enterprise. Research has found such trust to be more important than knowledge of genetics in predicting support for biotechnology (32). Trust in scientific institutions also predicts judgments of the risks and benefits of technologies, including nuclear power (33) and genetic modification (34). We examine how trust interacts with education and identity in predicting beliefs on these six issues, asking whether positive feelings toward science override the effects of knowledge and identity (35).

Results

Analytical Strategy. We examined each of the six science and technology issues separately, using the same modeling approach. For each, we first fit a model predicting participants' beliefs (coded such that higher values represent beliefs consistent with the scientific evidence) as a function of measures of their general education, science education, science literacy, political and religious identity, topical science knowledge (where available), trust in the scientific community, and demographics. These baseline models estimate the extent of religious and political polarization in beliefs about the six topics, as well as whether trust in the scientific community was related to those beliefs. To test whether religious and political polarization was greater among respondents with more education and scientific knowledge, we next fit six additional models for each of the six issues. Each new model added one interaction term to the baseline model. Each interaction term combined religious or political identity with one of the three education measures. For the two issues where the GSS included items testing topical scientific knowledge, climate change and nanotechnology, the baseline models also included terms for that knowledge and the additional regressions included interactions between that knowledge and religious and political identity. Finally, for each issue, we ran five additional models asking whether trust in the scientific community interacted with political and religious identity, and each of the three education measures. Given the large number of tests, as well as the large sample size, we only discuss results significant at $P < 0.01$, but also present results for $P < 0.05$, for readers' convenience.

Main Effects. Table 1 displays unweighted regressions for the six issues.

Education. Participants' general educational attainment and science education were at best weakly related to their acceptance of the scientific consensus. However, those with higher scientific literacy scores were more likely to agree with the scientific consensus on three issues: the Big Bang, human evolution, and nanotechnology. Those with more topical knowledge on nanotechnology and climate change were more likely to agree with the consensus on those issues (although the latter result was not statistically significant; *SI Appendix*, Tables S5 and S6).

Identity. Respondents who self-identified as more liberal on the measure of political conservatism were more likely to agree with the scientific consensus on four of the six issues: stem cell research, the Big Bang, human evolution, and climate change. Respondents who self-identified as being more liberal on the measure of religious fundamentalism were more likely to agree with the scientific consensus on an overlapping set of four issues: stem cell research, the Big Bang, human evolution, and nanotechnology. Beliefs about genetically modified foods were unrelated to either measure of identity.

Trust. Respondents who expressed greater trust in the scientific community were more likely to have beliefs consistent with its consensus (on all five items where both questions were asked). (In the 2010 GSS, the respondents who received the climate change item and the science literacy test did not receive the item on trust in the scientific community, so we could not include trust in the scientific community in those regressions. However, climate change belief and trust in the scientific community were positively correlated: $r = 0.14$, $P < 0.001$.)

Interactions with Identity. Next, we conducted six additional regressions for each of the six issues, adding terms for the interactions between the two forms of identity (political and religious) and the three measures of education (general education, science education, and science literacy) to the baseline models in Table 1. Table 2 reports the interaction terms from these models, and their effect sizes. The full models are reported in *SI Appendix*, Tables S2–S7. Negative interactions indicate greater polarization among more educated participants. Fig. 1 depicts the interactions with political conservatism, and Fig. 2 depicts the interactions with religious fundamentalism.

Political conservatism. Table 2 shows significantly greater polarization along political lines among participants with more general education for three issues: stem cell research, the Big Bang, and human evolution. There was more polarization among participants who had more science education for stem cell research, the Big Bang, human evolution, and climate change. Science literacy was associated with significantly greater polarization for stem cell research, human evolution, and climate change. Topical knowledge on nanotechnology and climate change was unrelated to political polarization (*SI Appendix*, Tables S5 and S6).

Table 1. Regressions predicting beliefs

Variable	Stem cell research	Big Bang	Human evolution	Climate change	Nanotechnology	Genetically modified foods
General education	0.011	0.105*	0.126*	0.238*	0.072	0.100
	(0.03)	(0.05)	(0.05)	(0.10)	(0.07)	(0.09)
Science education	0.137	−0.026	0.157	−0.583*	0.347	−0.039
	(0.07)	(0.13)	(0.13)	(0.26)	(0.18)	(0.20)
Science literacy	−0.019	0.165***	0.103***	−0.019	0.144***	0.092*
	(0.01)	(0.03)	(0.03)	(0.05)	(0.04)	(0.04)
Political conservatism	−0.160***	−0.186***	−0.280***	−0.232**	0.025	−0.084
	(0.02)	(0.04)	(0.04)	(0.07)	(0.06)	(0.06)
Religious fundamentalism	−0.189***	−0.447***	−0.733***	−0.165	−0.316**	−0.105
	(0.04)	(0.07)	(0.07)	(0.12)	(0.10)	(0.10)
Trust in science	0.224***	0.357***	0.332***		0.486***	0.436**
	(0.05)	(0.09)	(0.09)		(0.14)	(0.14)
Constant	3.202***	−1.890***	−0.088	4.442***	−1.823***	−0.484
	(0.15)	(0.28)	(0.27)	(0.47)	(0.48)	(0.43)
Observations	985	2,058	2,058	141	832	835
F	17.25***			3.14**		
R^2	0.15			0.18		
RSE	0.85			1.05		
Log likelihood		−1,174.61	−1,183.60		−504.45	−489.65
AIC		2,371.22	2,389.20		1,032.89	999.30

Logistic regressions (the Big Bang, human evolution, nanotechnology, and genetically modified foods) and linear regressions (stem cell research and climate change) predicting participants' beliefs, including as covariates polar knowledge, nanotechnology knowledge, age, gender (male/female), race (white/nonwhite), and a dummy variable for survey year. Full models are reported in *SI Appendix*, Tables S2–S7. SEs are shown in parentheses. We assessed the extent to which the predictors are multicollinear by calculating variance inflation factors; all were less than 2.13. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. AIC, Akaike information criterion; RSE, residual standard error.

Religious fundamentalism. Table 2 shows significantly greater polarization along religious lines among participants with more general education for three issues: stem cell research, the Big Bang, and human evolution. Science education was associated with significantly greater polarization on the Big Bang and human evolution. Higher science literacy scores were associated with significantly greater polarization on stem cell research. Topical knowledge on nanotechnology and climate change was unrelated to polarization (*SI Appendix*, Tables S5 and S6).

Interactions with Trust in the Scientific Community. We conducted regressions examining interactions between trust and identity (*SI Appendix*, Table S8) and between trust and education (*SI Appendix*, Table S9), predicting whether beliefs were consistent

Table 2. Interaction terms from separate regressions predicting beliefs

		Political conservatism			Religious fundamentalism		
Issue	Statistic	General education	Science education	Science literacy	General education	Science education	Science literacy
Stem cell research	Coeff.	−0.044**	−0.123**	−0.031***	−0.098***	−0.150*	−0.040**
	SE	(0.02)	(0.04)	(0.01)	(0.03)	(0.07)	(0.01)
	Partial eta sq.	0.009	0.010	0.019	0.011	0.005	0.009
Big Bang	Coeff.	−0.092**	−0.270***	−0.022	−0.214***	−0.400**	−0.065*
	SE	(0.03)	(0.07)	(0.01)	(0.06)	(0.13)	(0.03)
	OR	0.912	0.763	0.978	0.807	0.670	0.937
Human evolution	Coeff.	−0.081**	−0.269***	−0.037**	−0.210***	−0.592***	−0.046
	SE	(0.03)	(0.07)	(0.01)	(0.06)	(0.14)	(0.03)
	OR	0.922	0.764	0.963	0.810	0.553	0.955
Climate change	Coeff.	−0.051	−0.353**	−0.095***	0.158	0.138	−0.032
	SE	(0.05)	(0.13)	(0.03)	(0.10)	(0.24)	(0.05)
	Partial eta sq.	0.007	0.051	0.096	0.020	0.002	0.004
Nanotechnology	Coeff.	0.048	0.014	0.039	−0.03	−0.06	−0.044
	SE	(0.04)	(0.11)	(0.03)	(0.08)	(0.20)	(0.05)
	OR	1.049	1.014	1.040	0.970	0.942	0.957
Genetically modified foods	Coeff.	0.027	−0.053	0.002	−0.139	0.045	−0.019
	SE	(0.05)	(0.11)	(0.02)	(0.09)	(0.20)	(0.04)
	OR	1.027	0.948	1.002	0.870	1.046	0.981

Interactions between political conservatism and religious fundamentalism and general education, science education, and science literacy are estimated separately with unweighted linear (stem cell research and climate change) and logistic (the Big Bang, human evolution, nanotechnology, and genetically modified foods) regressions, including all covariates from Table 1. Full models are reported in *SI Appendix*, Tables S2–S7. SEs are shown in parentheses. Effect sizes are reported as partial eta-squared (partial eta sq.; for linear regression models) or odds ratio (OR; for logistic regression models). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. Coeff., coefficient.

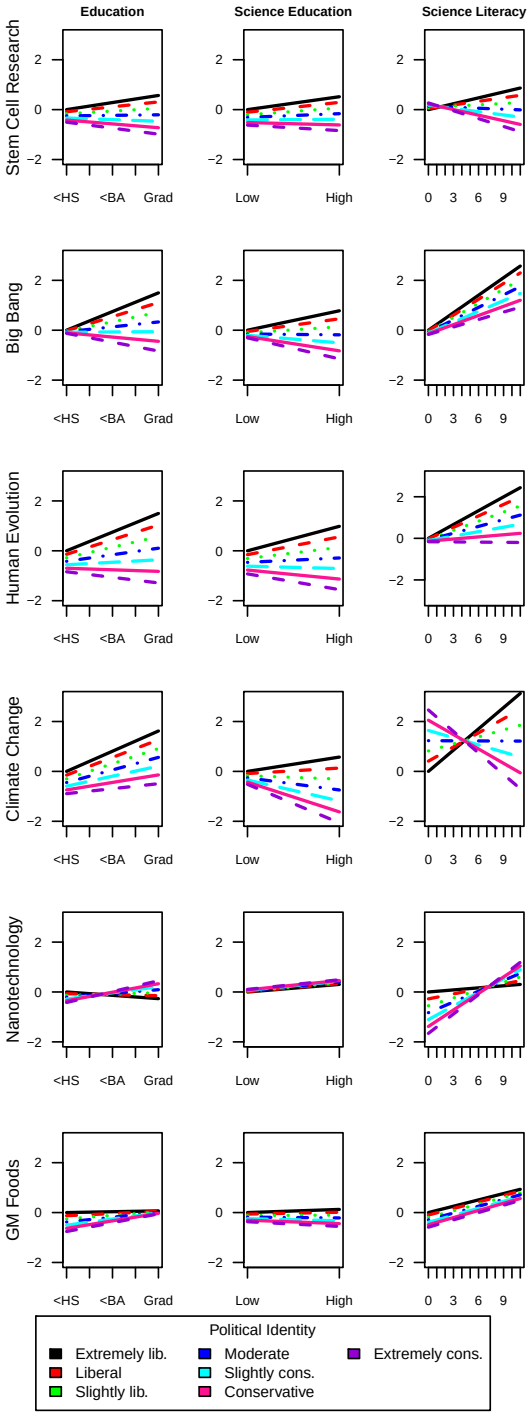

Fig. 1. Fitted values depicting interactions between political identity and general education (column 1), science education (column 2), and science literacy (column 3) for each of the six issues. The lines reflect participants' responses to the political identity measure: black line, extremely liberal (lib.); dashed red line, liberal; dotted green line, slightly liberal; alternating dot-dash dark blue line, moderate; dashed light blue line, slightly conservative (cons.); solid pink line, conservative; dashed purple line, extremely conservative. Fitted values were estimated with unweighted linear (stem cell research and climate change) and logistic [the Big Bang, human evolution, nanotechnology, and genetically modified (GM) foods] regressions, including all covariates from Table 1. Interactions from these regressions are reported in Table 2; full regression models can be found in *SI Appendix*, Tables S2–S7. HS, high school; BA, baccalaureate; Grad, graduate school.

with the scientific consensus. None were statistically significant at the $P = 0.01$ level.

Discussion

Prior research has found that political and religious polarization over science and technology issues in the United States can be greater among individuals with more education and science knowledge. We examine that potential pattern in responses to two waves of the nationally representative GSS (31), with respect to six issues: stem cell research, the Big Bang, human evolution, climate change, nanotechnology, and genetically modified foods. Overall, we found that where religious or political polarization existed, it was greater among individuals with more general education and among individuals with greater scientific knowledge, as measured by both whether they had taken science courses and how they scored on a test of science literacy. There were, however, no interactions between education and political or religious identity on two issues, nanotechnology and genetically modified foods, that have generated controversy but have not become part of these larger social conflicts in America. On all six issues, individuals with greater overall trust in the scientific community were also more likely to hold beliefs consistent with the scientific consensus. However, that trust did not interact with education or identity in predicting those beliefs.

These results are consistent with prior research, in finding both political and religious polarization of Americans' beliefs about scientific issues. Political identity was significantly associated with beliefs on four issues: stem cell research, the Big Bang, evolution, and climate change. Religious identity was significantly associated with beliefs regarding four, partially overlapping, issues: stem cell research, the Big Bang, evolution, and nanotechnology (but not climate change). For stem cell research, the Big Bang, human evolution, and climate change, polarization was greater for respondents who had more general education, more science education, and higher scientific literacy scores. Although political identify and religious identity were only somewhat correlated ($r = 0.19$), their patterns of polarization were similar on four of the six topics. The exceptions were that beliefs on nanotechnology were related to religious but not political identity, whereas beliefs on climate change were associated with political but not religious identity. The latter finding echoes a recent survey finding, after controlling for demographics including political views, no relationship between religious affiliation or frequency of church attendance and climate change beliefs (36). The effects of education and identity on beliefs were unrelated to general trust in the scientific community.

Our main result, that general education, science education, and science literacy are associated with greater political and religious polarization, is consistent with both the motivated reasoning account, by which more knowledgeable individuals are more adept at interpreting evidence in support of their preferred conclusions, and the miscalibration account, by which knowledge increases individuals' confidence more quickly than it increases that knowledge. Speculatively, better educated people are more likely to know when political or religious communities have chosen sides on an issue, and hence what they should think (or say) in keeping with their identity. At the time of the surveys, positions on genetically modified foods had not polarized along religious or political lines. Although some religious groups had taken positions on nanotechnology, they had not publicized those views enough for most people to know them, however well educated (37).

One strength of these analyses is their use of responses from a large, nationally representative sample from a premier survey, the GSS. As with any secondary analysis, they were limited to the questions asked by the original investigators, guided by their own research interests. That is a strength, in that those interests were largely independent of our own, reducing the risk of biased questions or shared method variance (38). It is also a weakness,

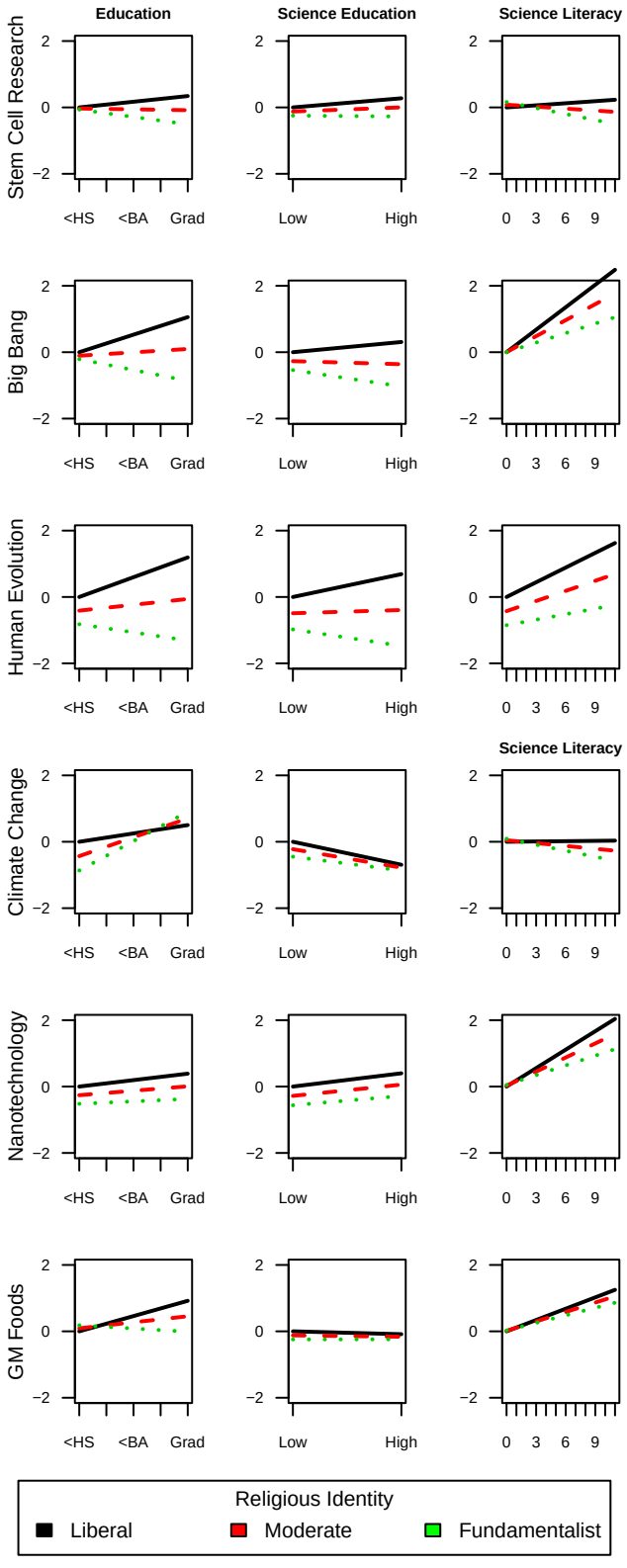

Fig. 2. Fitted values depicting interactions between religious identity and general education (column 1), science education (column 2), and science literacy (column 3) for each of the six issues. The lines reflect participants' responses to the religious identity measure: solid black line, liberal; dashed red line, moderate; dotted green line, fundamentalist. Fitted values were estimated with unweighted linear (stem cell research, climate change) and logistic [the Big Bang, human evolution, nanotechnology, and genetically modified (GM) foods] regressions, including all covariates from Table 1. Interactions from these regressions are reported in Table 2; full regression models can be found in *SI Appendix*, Tables S2–S7. HS, high school; BA, baccalaureate; Grad, graduate school.

in that we could not probe potential explanations for the findings in any depth, meaning that further research is needed to clarify the roles of the (nonexclusive) causal mechanisms, as suggested above, that might underlie the correlation between science knowledge and identity-based polarization.

A second limitation of the analyses is that positions on specific issues can change over time. Since the time of the surveys (2006 and 2010), associations between religious and political identity and beliefs regarding science and technology issues may have shifted, potentially as a result of changes in religious and political discourse that could have emphasized (or deemphasized) connections between identity and beliefs regarding science and technology issues. For example, we found little association between religious identity and climate change beliefs in our data. However, recent efforts by religious leaders, such as Pope Francis' encyclical, have emphasized how taking action on climate change is consistent with Christian values, which could alter the observed relationship between religious identity and climate change beliefs (39). Additionally, public opinion on science and technology issues can vary by country, as can its relationship to political and religious identity; the analyses presented here are specific to the United States and may not generalize to other countries. Whether education is causally related to identity-based polarization is an open question, bearing further inquiry.

An additional limitation of these analyses is that the interpretation of several GSS belief measures is hampered by their use of double-barreled wording. An affirmative answer to the item on stem cell research requires agreeing both that the research is worthwhile and that the government should spend money on it. The item on climate change asks participants to assume that climate change is happening and then to express their level of concern, despite the well-documented finding that a significant minority of Americans dispute its existence (40). The questions on human evolution and the Big Bang do not allow participants to distinguish what scientists believe and what they themselves believe (ref. 41, pp. 7–46). The question about genetically modified food offers no way for individuals concerned about ecological effects to express themselves (42). Speculatively, better educated individuals might have been more attuned to these wording issues, with unclear impacts. Those who found questions ambiguous might have responded to their perceived gist, adding noise to their answers. Those who found questions loaded might have responded to the perceived bias in their wording, bringing polarized public discourse into the survey.

Overall, our results suggest that education, whether measured in terms of general educational attainment, science educational attainment, or science literacy scores, may increase rather than decrease polarization on issues linked to political or religious identity. That pattern may reflect greater knowledge of when issues have divided along identity lines, greater ability to defend such beliefs, or greater confidence in one's own knowledge. Understanding these mechanisms can guide science communication so that the evidence gets through before it no longer matters (43, 44).

Methods

This research was approved by the Institutional Review Board of Carnegie Mellon University. The code used for these analyses is available from the corresponding author.

Data. Data for these analyses are from the 2006 and 2010 GSSs (31). The GSS is a biennial nationally representative survey administered by the National Opinion Research Center at the University of Chicago. GSS data are publicly available at https://gssdataexplorer.norc.org. Informed consent was obtained

from participants; documentation on participant recruiting and informed consent is available at gss.norc.org. We selected the 2006 and 2010 GSSs for analysis because they included questions on six contested issues: stem cell research, the Big Bang, human evolution, climate change, nanotechnology, and genetically modified foods, along with a science literacy test and standard sociodemographic measures. We report unweighted results in the main text, combining data from the 2006 and 2010 samples; we describe data selection and weighting procedures in *SI Appendix, SI Methods*.

Measures. All measures were identical in both 2006 and 2010, except that the genetically modified foods items were administered only in 2006 and the measure of climate change belief was administered only in 2010.

Identity. Self-reported political conservatism was elicited on a seven-point scale ranging from extremely liberal to extremely conservative. Self-reported religious fundamentalism was elicited on a three-point scale, asking participants to indicate whether their religion was liberal, moderate, or fundamentalist.

Trust in the scientific community. Participants were asked, "As far as the people running these institutions [the scientific community] are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?"

Education. General education was measured as the highest level of education attained, on a scale from 0 = did not finish high school to 4 = obtained a graduate degree. Science education was measured as a binary variable; participants were labeled as having "high" science education if they had taken both a high-school science class (biology, chemistry, or physics) and a college-level science course (where "science" was not defined); otherwise, they were labeled as having "low" science education.

Science literacy. We summed participants' scores on modified versions of two science literacy scales constructed by Miller (45); scores ranged from 0 to 11 (*SI Appendix, SI Methods*).

Topical scientific knowledge. We included a polar knowledge measure comprising participants' scores on a five-item polar knowledge scale (5, 17) and a binary nanotechnology knowledge variable (*SI Appendix, SI Methods*).

Demographic measures. We considered three measures: age, gender, and race (coded as white/nonwhite).

Beliefs on controversial scientific topics. We selected six GSS questions on which we could assess whether participants' beliefs were consistent with scientific evidence. We recoded all responses so that higher values represent beliefs consistent with that evidence; full details of the recoding are available in *SI Appendix, SI Methods*.

Participants. The GSS recruited more participants in 2006 (4,510) than in 2010 (2,044). As not all participants received all items and some items had missing data, we report the number of responses used in each analysis. The composition of the sample in both years was very similar, as reported in *SI Appendix, SI Methods*.

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