frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 18 June 2025
DOI 10.3389/feduc.2025.1556464

Check for updates

OPEN ACCESS

EDITED BY
Subramaniam Ramanathan,
Independent Researcher, Singapore, Singapore

REVIEWED BY
Taniya Jayani Koswatta,
University of Nevada, Reno, United States
Elena De Gioannis,
University of Milan, Italy

*CORRESPONDENCE
Kevin Mark Roessger
kmroessg@uark.edu

RECEIVED 06 January 2025
ACCEPTED 19 May 2025
PUBLISHED 18 June 2025

CITATION
Roessger KM and Greenleaf AT (2025) Learning to support science: gender differences in how scientific literacy mediates formal education's effect on U.S. adults' public support for science. *Front. Educ.* 10:1556464.
doi: 10.3389/feduc.2025.1556464

COPYRIGHT
© 2025 Roessger and Greenleaf. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Learning to support science: gender differences in how scientific literacy mediates formal education's effect on U.S. adults' public support for science

Kevin Mark Roessger[1]* and Arie Todd Greenleaf[2]

[1]Department of Counseling, Leadership, & Research Methods, University of Arkansas, Fayetteville, AR, United States, [2]Department of Counseling, Nova Southeastern University, Fort Lauderdale, FL, United States

Introduction: Scientific literacy is targeted by the *knowledge deficit model*, which predicts that increased scientific literacy improves public support for science. The model, in part, assumes formal education drives scientific knowledge, which, in turn, drives support for science. To date, though, this relationship is unclear, and research shows that, while formal education is associated with adults' public support for science, scientific literacy maintains only a small relationship with support for science, one that may differ by gender.

Methods: Using a conditional process analysis, we drew on 2018 General Social Survey data to examine whether scientific literacy mediates education's effects on support for science and whether this relationship differs by gender.

Results: We found that scientific literacy partially mediates the effect of formal education on public support for science: As formal education increases, so does scientific literacy, which in turn increases support for science. This relationship differed markedly by gender. For men, education improved support for science only through scientific literacy gains, whereas for women, education improved support for science regardless of scientific literacy.

Discussion: Our findings demonstrate a key assumption of the knowledge deficit model, namely that, overall, more education leads to more scientific literacy, which in turn leads to greater public support for science. Considered alone, though, these findings ignore substantial gender differences. Specifically, the mediational process assumed by the knowledge deficit model occurred only in men. It was an inaccurate account of formal education's effect in women. This may be a principal reason why the knowledge deficit model is roundly criticized as inadequate for addressing public communication of science.

KEYWORDS

formal education, scientific literacy, public support for science, gender, science technology engineering mathematics (STEM)

Introduction

In an era of rapid technological advancement and information dissemination, governments have come to rely on public support for science to successfully address emergent social challenges. Nowhere is this more pronounced than in democracies like the United States, where scientific research, even decisions about what scientific questions are pursued, depends on public funding and political support, and often on the needs and values of the public (Pamuk, 2021). To ensure a future of economic prosperity and informed democracy, it is perhaps more critical than ever to adopt educational policies and practices that foster and develop public support for science.

Such support would seem assured given how public concerns drive some of the world's most pressing scientific challenges. From the development of mRNA-based COVID-19 vaccines (Dolgin, 2021); to the creation of technologies for producing, converting, and storing clean energy (Woolston and Ong, 2022); to the construction and evaluation of strategies for reducing plastic pollution (Lau et al., 2020)—scientific research continues to tackle problems affecting nearly everyone. Yet, paradoxically, scientists' efforts are often made contingent upon funding that is closely tied to what the public deems immediately useful (Yin et al., 2022). This presents a problem in that the practical benefits of scientific research, particularly those emerging from basic research, are not always immediately salient (Lee, 2019). More troublesome is how public support has become threatened by political polarization, compelling some to disregard scientific facts that are inconsistent with their political identity or, more broadly, to adopt political ideologies that contest science as a public endeavor (Rekker, 2021). No longer able to assume public support, scientists have grown inured to under-funded programs and declining policy influence (Gauchat, 2015).

Education and scientific literacy

One activity long thought to bolster public support for science is formal education. Adults with more formal education are more likely to support further funding of scientific research (Hallman, 2017; Miller et al., 1997; Muñoz et al., 2012; Sanz-Menéndez et al., 2014; National Science Board, 2014, 2020). For some who progress to higher education, increased support for science often comes regardless of one's major, possibly because all bachelor's degree programs in the U.S. require students complete at least 1 year of science coursework. Yet interestingly, increases in both adults' non-science coursework and science coursework are associated with stronger support for science (Bak, 2001). One manner by which non-science coursework accomplishes this is through helping adults better understand government spending. Goldfarb and Kriner (2017) showed that adults who overestimate the size of the U.S. science budget are less likely to support further science spending, all else being equal. That is, highly educated adults provide more accurate estimates, leading to greater support for science funding. Science coursework, however, is thought to bolster public support for science more directly by helping adults better understand scientific terms, concepts, and processes (Kennedy and Hefferon, 2019; National Science Board, 2016, 2018, 2020). This collected knowledge, commonly termed *scientific literacy*, has historically been defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Research Council, 1996, p. 22). More recently, the construct has been defined as a collection of domain-specific competencies in scientific content, procedures, and epistemology; broadly described as a person's ability to "explain phenomena scientifically; evaluate and design scientific enquiry; and interpret data and evidence scientifically" (OECD, 2017a, p. 1).

Some within the science education community have dismissed the idea of scientific literacy, calling it an empty slogan that offers little guidance for science education (Rudolph, 2024). Others have questioned the content and validity of commonly used measures of the construct, such as that used with children and adolescents in the Programme for International Student Assessment (PISA) (Lau, 2009; Le Hebel et al., 2014; Nentwig et al., 2009). Still, science education researchers across international contexts continue to consider scientific literacy a meaningful outcome for informing decisions related to science education content, practices, and policies (Bruckermann et al., 2023; Gericke and Mc Ewen, 2023; Liou, 2021; Teig et al., 2020; She et al., 2019). Among these researchers, no consensus exists on how the construct should be operationalized. Yet all consider it a multidimensional construct, comprised of educational competencies and knowledge related to science within the cognitive and affective domains of learning. These competencies and knowledge include the ability to explain scientific phenomena, evaluate scientific inquiry, and interpret data and evidence (OECD, 2016); to read and write in a scientific discipline (Norris and Phillips, 2003); to recognize and recall domain-specific scientific knowledge (Kampa and Koeller, 2016; Norris and Phillips, 2003; OECD, 2017b); to apply scientific reasoning skills (Kampa and Koeller, 2016); and to apply scientific knowledge in different contexts while valuing science (OECD, 2017b).

Scientific literacy's close relationship with knowledge has made it the historic target of the *knowledge deficit model*, which predicts that by increasing scientific literacy, governments can increase public support for science (Motta, 2019). This model has long assumed a mediational relationship between formal education, scientific literacy, and public support; namely that more education means more scientific knowledge, which, in turn, means greater public support for science (Bak, 2001). Indeed, measures of scientific literacy commonly use knowledge-based questions sometimes critiqued as "textbook science" or formal schooling proxies (Miller, 2022). It is perhaps unsurprising then that, just as the knowledge deficit model would predict, adults with more formal education express greater support for scientific research (Hallman, 2017; Miller et al., 1997; Muñoz et al., 2012; Sanz-Menéndez et al., 2014; National Science Board, 2014, 2020).

But whether this support comes from what Chakravartty (2023) calls *scientific knowledge* or *knowledge of science* is unclear. Must formal education produce gains in the former, or can it improve support for science simply by increasing the latter, focusing less on scientific facts, theories, and processes than on critical thinking and science's ability to produce positive changes in people's lives? Miller et al. (2022), for instance, showed that, after controlling for scientific literacy, gains in educational attainment are still positively associated with adults' attitudes toward scientific issues

(Miller et al., 2022). Achterberg et al. (2017) also showed that greater education levels, regardless of major, are associated with greater trust in scientific institutions (Achterberg et al., 2017). Similar findings with public support for science would challenge the comprehensiveness of the knowledge deficit model and its ability to guide educational practices and policy. To date, however, mediational studies have yet to empirically demonstrate the model's implied relationship between formal education, scientific literacy, and support for science. This gap in the literature has become more salient with the arrival of competing views, such as the dialogue model, which claim non-scientific forms of knowledge are equally important in developing people's support for science (Reincke et al., 2020). Educators and policy makers concerned with increasing public support for science are therefore presented with a problem. Must they focus on improving scientific literacy, or can they target educational attainment in general, broadening other forms of knowledge as well as adults' abilities to think and evaluate science's role in addressing societal challenges. To address this problem, this study seeks to first understand whether the knowledge deficit model accurately depicts the relationship between formal education, scientific literacy, and public support for science in adults.

Although the model's validity remains unclear, some educators and scientists continue to assume the model is accurate for all, prioritizing the need to inform the public of scientific facts and practices over the need to excite them or build trust (Dudo and Besley, 2016). Even with just-in-time informal learning and mobile technologies now a ubiquitous part of modern life, science communicators continue to claim that basic scientific literacy is an essential entry point to people's understanding of science. At a minimum, Miller (2022) describes this foundational knowledge as "a functional vocabulary of scientific constructs, some sense of the spelling of key words and constructs, and a general schema of the nature of matter, energy, DNA, cells, and the evolution of life on this planet" (p. 270).

This continued focus on scientific literacy in education has produced consistent gains in U.S. adults over several decades (Miller, 2015). Yet despite this, scientific literacy continues to exhibit only a small, positive relationship with support for science funding, all else being equal (Hallman, 2017; Sanz-Menéndez et al., 2014: Muñoz et al., 2012). So tenuous is it that some have suggested the relationship must be moderated by such factors as religiosity or political ideology (National Academies of Sciences, Engineering, and Medicine, 2016). To date, this claim remains unexplored, yet several studies have examined the possibility among general scientific concerns (Hamilton, 2008; Hamilton, 2011; Hamilton et al., 2012). These studies have found that although conservative ideologies attenuate the relationship, scientific knowledge maintains a positive effect across all but the most conservative. Given the relatively small proportion of U.S. citizens identifying as such—estimates place the "very conservative" at 9 percent of the population (Saad, 2022)—it is unlikely that ideology alone accounts for scientific literacy's surprisingly small effects on public support for science.

The primary purpose of this study, then, is to test the presumed mediational relationship between formal education, scientific literacy, and public support for science. In the following section, we outline the grounds for this study's secondary purpose: to explore the possibility of differential effects between groups, a possibility that may explain the small relationship commonly found between scientific literacy and public support for science. Ahead, we outline how systems justification theory and empirical research suggests this relationship may differ in men and women. If accurate, this may show that previous conclusions based on a homogeneity of effects assumption are misleading and that the model may not accurately depict the nature of this relationship for everyone.

Gender differences

A number of researchers have examined how gender may moderate relationships between scientific knowledge and science-related positions. Algara et al. (2020) examined differences in how men and women express scientific knowledge and support for COVID-19 government containment polices. Using an overall composite measure of peoples' support for seven government restrictions, they found that, across political parties, increased scientific knowledge was associated with increased support in women yet decreased support in men. This surprising finding suggests that in addition to a widely reported gender gap in overall levels of scientific literacy (Hayes and Tariq, 2000; Kennedy and Hefferon, 2019), men and women may use scientific literacy differently when forming opinions on science policy and funding. Algara et al. (2020) speculate this may stem from women having higher overall levels of compassion, trust in government, and support for prosocial policies—qualities, they argue, that are triggered only when requisite levels of scientific knowledge have been reached. Similarly, Whitman-Cobb (2020) recently showed that, all else being equal, scientific knowledge plays a greater role in women's support for further space funding. Consistent with these findings, others have illustrated that men and women adopt different positions on science topics after scientific knowledge and education are held constant, raising the possibility that the strength or direction of the relationship between scientific literacy and support for science may differ in men and women. For instance, Cassese et al. (2020) found that women were less likely than men to endorse COVID-19 conspiracy theories, after controlling for salient variables, including political party, education, and scientific knowledge. This finding was partially attributed to specific dispositional factors in women (i.e., lower levels of learned helplessness and conspiracy thinking). Similarly, Steel et al. (2010) found that among the general population, women were more likely to support greater involvement of scientists in policy making, after controlling for political ideology, environmental attitudes, and education levels.

System justification theory

One possible explanation for how men and women may use scientific literacy differently comes from *system justification theory*. System justification theory describes how people exposed to a criticism of their social system become motivated to restore a sense of legitimacy and stability to it, often at a nonconscious level (Jost and Banaji, 1994; Jost, 2019). This motivation is especially strong among those who depend on a system for their existence and livelihood (Jost, 2020). Science is a social system (Erduran and Dagher, 2014), one with an increasing and persisting gender gap dominated by men (Huang et al., 2020; National Center for Science and Engineering Statistics, 2023). Within this system, men have historically enjoyed privileges consistent with being a *high-status group*, whereas women have historically suffered inequalities consistent with being a *low-status group*. From 1955 to 2016, for instance, men have authored 73% of all peer-reviewed scientific articles published globally (Huang et al., 2020). Men still hold 65% of all U.S. jobs in science, technology, math, and engineering (STEM; National Center for Science and Engineering Statistics, 2023); and they continue to earn $20,000 annually more than women on average in the U.S. STEM workforce (Charlesworth and Banaji, 2019). Men have also been overrepresented at the highest levels of science for most of the 20th and 21st centuries. Since its inception, the National Academy of Science has welcomed mostly men as its members until only recently when women surpassed them in the discipline of psychology (Card et al., 2022). Perhaps unsurprisingly, then, these historic gender gaps have informed, or been informed by, people's views of gender and science. Carli et al. (2016) report that both men and women perceive men to have personalities more characteristic of successful scientists than women. Public representations of scientists in online science education resources appear to follow, depicting men more often within a science profession and women more often as teachers (Kerkhoven et al., 2016).

As the historic high-status group within science, men may have come to identify more strongly with the idea of being a scientist or being scientifically minded. Accordingly, system justification theory would predict that they not only work to justify the system of science when it is threatened, but they show greater implicit *ingroup favoritism* toward themselves and their perceived role as scientists. Indeed, Kray et al. (2017) found that men's defense of a system and its *status quo* is often motivated by their membership in a higher status group within that system's social hierarchy. Within the system of science, this may manifest as a greater tendency to gain and articulate scientific knowledge as a way of legitimizing science, their support for it, and their perceived role as scientists or scientifically thinking laypeople. In a sense, men will engage in a form of psychological overcompensation (Dixon et al., 1995). Gaining and demonstrating scientific literacy will not only help them defend science against its critics, but also maintain science's historic social order that privileges them.

Women, however, have long been marginalized by science and are less likely to have identified as scientists or scientifically-minded laypeople. System justification theory would predict that, as the low status group in this system, women would demonstrate support for the *status quo*, as well as an implicit *outgroup favoritism* toward scientists, relinquishing their interests in parity in favor of their basic needs for certainty, security, and social conformity (Jost and Banaji, 1994). Support for science may even be strongest among those women who least identify with it because they see no hope of parity in the future but still wish to satisfy these basic needs (Jost et al., 2004). When science is threatened, then, women may demonstrate less of a tendency to legitimize science through gaining and articulating scientific knowledge, the currency of the outgroup. Instead, their willingness to support science may be based more on unrelated considerations, such as prosocial values (Lizotte, 2020) and perceived efficacy of government programs (Schlesinger and Heldman, 2001). Indeed, even among established scientists, Dudo and Besley (2016) found that men were more likely to express scientific knowledge as a way of defending science against misinformation, whereas women were more likely to express scientific knowledge as a way of educating the public. This finding mirrors how system justification theory would predict the behavior of high-status and low-status groups within a system that comes under threat (Jost et al., 2004): men would exhibit increased ingroup favoritism by working to justify their position as scientists or scientifically minded laypeople, whereas women would exhibit increased outgroup favoritism by supporting the men as scientist idea as well as the system that has historically espoused this idea. In other words, both men and women would continue to support science as a system, but only men would feel compelled to justify their positions as scientists; women would look for reasons to support the system that avoid challenging its historic *status quo*.

This claim should be considered in light of wide gender disparities in adults' choices of college majors. Although women make up 57% of the U.S. undergraduate population, they represent only 21% of computer science majors, 24% of engineering majors, and 24% of physics majors (National Center for Science and Engineering Statistics, 2023). Such disparities exist alongside educational policies that have sought gender parity in education since the early 1970s, such as Title IX of the Education Amendments Act of 1972 and the Women's Educational Equity Act of 1974 (Madigan, 2009). While the U.S. remains the only member nation within the Organization for Economic Cooperation and Development without federally mandated maternity leave (Kahn, 2020) —a policy failure that disproportionately affects women and likely furthers their historical group status within science—it is unlikely that this alone affects preferences for certain majors over others.

A more likely explanation for the persistence of the gender gap in science is the complex interplay between research illustrating gender-specific preferences (Diekman et al., 2011; Stoet and Geary, 2018), beliefs related to gender and science (Carli et al., 2016; Mascret and Cury, 2015), and an absence of U.S. policy for eliminating the gender gap. Stoet and Geary (2018), for instance, showed that while adolescent girls have similar or better scientific literacy than boys in most countries, they obtain fewer STEM degrees in all countries. This gender gap is larger in more gender-equal countries that offer greater opportunities for women. Stoet and Geary called this the *gender-equality paradox*, arguing that when girls have greater life satisfaction and economic opportunity, they choose degrees based on personal strengths and preferences rather than economic benefits or the ability to ameliorate hardships. The implication is that STEM fields more often align with men's strengths and preferences, so when everyone is free to choose, men choose STEM majors more often. This provides men an opportunity to surpass women in scientific literacy, which further justifies their perceived position as scientists or scientifically minded laypeople.

In the current study, we tested these claims by first examining the presumed mediational relationship between formal education, scientific literacy, and public support for science. We then examined gender differences through the lens of system justification theory to see if men and women's education levels and scientific literacy were differentially associated with their views of science funding. Our aim was to inform educational practices and policies directed toward equitably promoting public support for science through formal education.

The current study

Drawing on these theoretical and empirical insights, we examined data from the 2018 General Social Survey's (GSS) science survey module to determine whether, and to what degree, scientific literacy mediates formal education's effects on public support for science. We then examined whether the strength or direction of this mechanism differs for men and women.

Research questions and hypotheses

Three research questions guided this study (hypothesis in parentheses):

1. Is there a relationship between U.S. adults' formal education and public support for science? (Yes, as formal education increases so does the likelihood of having stronger public support for science)

2. Is this relationship mediated by scientific literacy? (Yes, the effect of formal education on public support for science is partially mediated by scientific literacy.)

3. Does the mediating relationship between formal education, scientific literacy, and public support for science differ for men and women? (Yes, the mediational process is greater in men than women.)

Methods

Data

Data for this study were drawn from the 2018 General Social Survey (GSS), a nationally representative cross-sectional survey of U.S. adults designed to monitor changes in opinions, attitudes, and behaviors in American society. Participants are selected and interviewed in-person to generate a representative sample of noninstitutionalized adults living in the U.S. The GSS is one of the longest continuously running sociological surveys in the U.S. Since 1972, it has been funded by the National Science Foundation, and since 1994, conducted biennially by the National Opinion Research Center at the University of Chicago. To date, its publicly accessible data have been used in over 32,500 scholarly books, articles, and dissertations (GSS, 2021). Survey data are made available to the research public 2 years after their collection. At the onset of the COVID-19 pandemic, this was further delayed, making 2018 data first available at the time this research was conducted in late 2020.

In addition to its established history in academic research, the GSS was chosen here for two reasons. First, it representatively samples this study's population of interest: U.S. adults (18+). Second, it measures both adults' formal education as well as their scientific literacy (e.g., Allum et al., 2018; Gauchat, 2012; Makarovs, 2021; Tourgangeau et al., 2016). The other most commonly used nationally representative survey of adults, OECD's Programme for the International Assessment of Adult Competencies (PIAAC), does not measure scientific literacy.

Importantly, the GSS has several notable limitations related to its small sample size of 3,000. Beveridge (2007) has argued that, although its full probability sample of 3,000 allows researchers to track patterns of U.S. behavior and attitudes over time, it fails to provide this for geographical sub-groups or particular races of ethnic groups. It also fails to allow researchers to track changes at the individual level over time, or to consider contextual or spatial variables relevant to behaviors and attitudes in specific neighborhoods or locations.

TABLE 1 Missing data from GSS's science survey module collected in 2018 (sample size = 1,175).

		Missing	
Variable	Responses	Count	Percent
Public support for science (NATSCI)	1105	70	6.0
Formal education (EDUC)	1171	4	0.3
Scientific literacy	1175	0	0
Gender (SEX)	1175	0	0
Age (AGE)	1170	5	0.4
Conservativism (POLVIEWS)	1127	48	4.1
Religiosity (FEELREL)	1156	19	1.6
Race (RACE)	1175	0	0
Income (INCOME)	998	177	15.1

In the current study, data for the GSS's *science survey module* were collected in 2018 from 1,175 adults (18+) living in the United States. Respondents were interviewed for 90 min, and all completed the survey in either English or Spanish. Residents of institutions and group quarters were not interviewed. Of the 1,175 respondents, 903 (76.9%) provided usable values for all variables in this analysis. A response of "don't know" (DK), "no answer" (NA), "inapplicable" (IAP) or "refused" was deemed missing for all items but those comprising the scientific literacy variable. Responses of "don't know" for this variable were deemed incorrect. A listing of the frequency and percentage of missing data for each variable can be found in Table 1. Of the 10,575 possible values in the dataset, 323 were missing (3.1%). A multiple imputation procedure (5 iterations) was then used to impute replacement values for these missing data.

The final dataset consisted of 58.7% women and had a racial makeup (as measured by GSS) of 71.7% White, 16.3% Black, and 11.9% Other. Respondents averaged 50.0 years of age (SD = 18.12) and 13.7 years of formal education (SD = 3.02). To account for the GSS's stratified, multistage sampling design, survey weights were applied to all subsequent analyses. Descriptions of GSS variables that follow are accompanied by official GSS mnemonics in parentheses.

Dependent variable

The dependent variable for this study was a respondent's *public support for science* (NATSCI). To measure this, respondents were first read a general set of directions:

We are faced with many problems in this country, none of which can be solved easily or

TABLE 2 Items comprising the civic scientific literacy scale (correct responses in parentheses).

1. The center of the Earth is very hot [HOTCORE]. (True)
2. All radioactivity is man-made [RADIOACT]. (False)
3. It is the father's gene that decides whether the baby is a boy or a girl [BOYORGIRL]. (True)
4. Lasers work by focusing sound waves [LASERS]. (False)
5. Electrons are smaller than atoms [ELECTRON]. (True)
6. Antibiotics kill viruses as well as bacteria [VIRUSES]. (False)
7. The universe began with a huge explosion [BIGBANG]. (True)
8. The continents on which we live have been moving their locations for millions of years and will continue to move in the future [CONDRIFT]. (True)
9. Human beings, as we know them today, developed from earlier species of animals [EVOLVED]. (True)
10. Does the Earth go around the Sun, or does the Sun go around the Earth [EARTHSUN]? (Earth around Sun)
11. How long does it take for the Earth to go around the Sun: 1 day, 1 month, or 1 year [SOLARREV]? (1 year)
12. Now think about this situation. A doctor tells a couple that their genetic makeup means that they've got one in four chances of having a child with an inherited illness. A. Does this mean that if their first child has the illness, the next three will not have the illness [ODDS1]? (No)
13. B. Does this mean that each of the couple's children will have the same risk of suffering from the illness [ODDS2]? (Yes)
14. Now, please think about this situation. Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to one thousand people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to five hundred people with high blood pressure, and not give the drug to another five hundred people with high blood pressure, and see how many in both groups experiences lower blood pressure levels. Which is the better way to test this drug [EXPDESGN]? (500 get the drug and 500 don't)

inexpensively. I'm going to name some of these problems, and for each one I'd like you to tell me whether you think we're spending too much money on it, too little money, or about the right amount.

Respondents were then asked, "Are we spending too much, too little, or about the right amount on supporting scientific research?" Only responses of a) too much, b) about right, or c) too little were included in the analysis. Response rates were as follows: too much (8.2%), about right (47.9%), and too little (43.8%).

The three-category variable was then recoded into two dummy-coded variables, with too much serving as the reference category of each: a) too little or too much and b) about right or too much. Recoding was done because retaining the variable in its original ordered three-category form produced violations of the proportional odds assumption of ordinal regression analysis. This created two datasets for all subsequent analyses: one for those responding too much or too little, referred to as the polarized sample ($N_{polarized}$ = 577, $n_{toomuch}$ = 99, $n_{toolittle}$ = 478); another for those responding about right or too little, referred to as the contiguous sample ($N_{contiguous}$ = 627, $n_{toomuch}$ = 99, $n_{aboutright}$ = 528). Women comprised 58.9% and 57.7% of the two samples, respectively, closely matching their representation in the larger, unsplit dataset (women = 58.7%).

Independent variable

The principal independent variable was a respondent's highest year of formal education (EDUC). Formal education is defined as "education that is institutionalized, intentional, and planned through public organizations and recognized private bodies" (UNESCO, 2012, p. 11). Within the U.S., this refers to years completed within a primary, secondary, and postsecondary educational institution. Values were self-reported and ranged from 0 to 20. In the current study, we intentionally selected a continuous measure of formal education depicting years of education rather than degree attainment. We did this to account for the over 40 million U.S. adults who have completed some college, yet failed to earn a credential (Causey et al., 2023). Because our dependent variable is a measure of attitudes rather than income or employment, we hypothesize that any formal education, even that which doesn't result in a degree, is influential. This is a particularly salient assumption in the era of lifelong learning, wherein adults frequently use formal education for certificates as part of their continuing professional development.

Mediating variable

The mediating variable was a respondent's scientific literacy. The GSS science survey module includes nine true/false questions and two multiple-choice questions that measure respondents' knowledge of basic science facts. These questions are paired with three additional multiple-choice questions assessing respondents' understanding of scientific processes, specifically probability and experimental design. Together, these 14 questions are commonly used as a composite measure of civic scientific literacy (Allum et al., 2018; Gauchat, 2012; Makarovs, 2021; Tourgangeau et al., 2016). In this study, the number of correct answers to these questions served as the scientific literacy measure (Range: 0–14, M = 9.05, SD = 3.03). A list of items comprising this measure along with their official mnemonics and correct responses is featured in Table 2.

Moderator

The moderating variable was a respondent's gender. Gender has been found to covary with adults' perceived science knowledge (BEIS and Department for Business, Energy and Industrial Society, 2020) and public support for science (Giffoni and Florio, 2023). The gender measure used here was coded silently by the interviewer as either male or female (SEX).

Covariates

Four respondent background variables measured in the GSS were used as covariates: age, conservatism, religiosity, income,

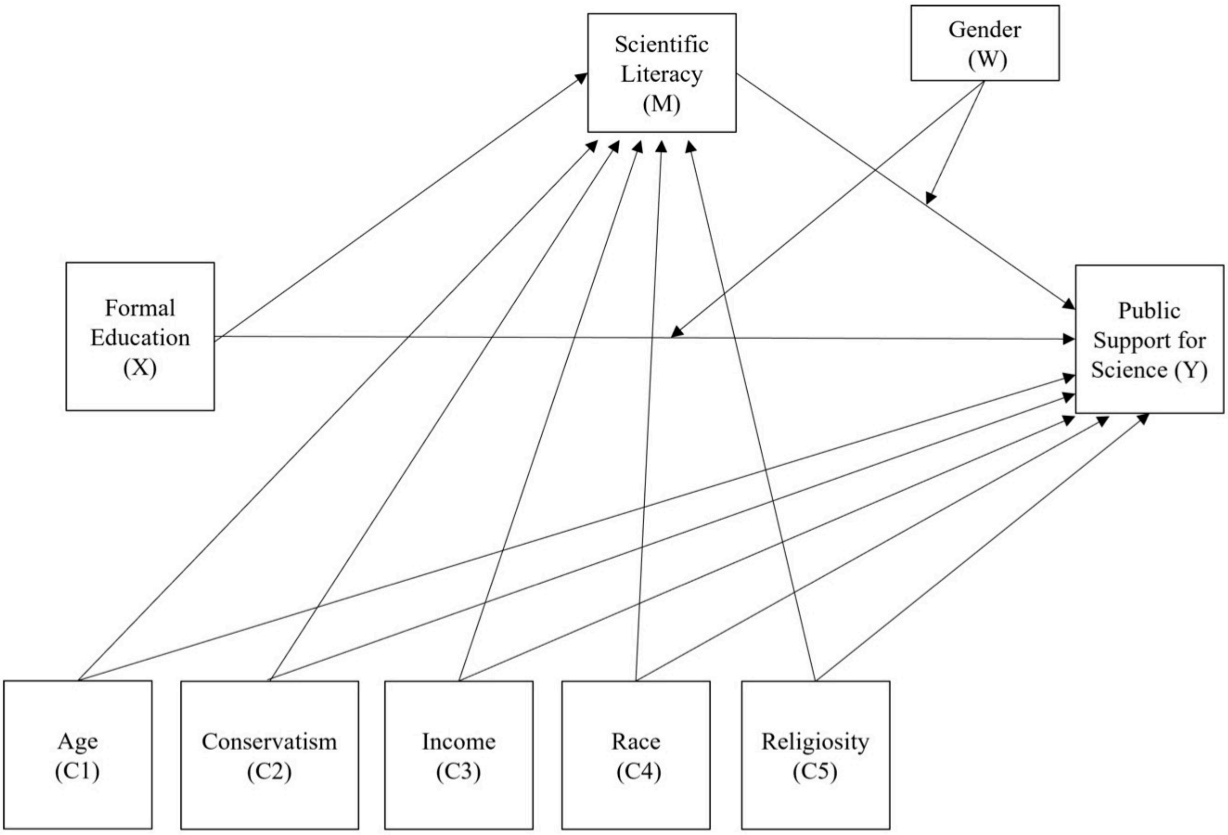

FIGURE 1
A Conceptual diagram of the relationship between U.S. adults' formal education and public support for science as mediated by scientific literacy, conditional on gender.

and race. Age has been controlled for in previous analyses of adults' attitudes toward science (Allum et al., 2008) and public support for science (Florio et al., 2020; Giffoni and Florio, 2023). In the current study, age was measured as respondents' self-reported age in years (AGE). Political and religious ideologies have also been found to covary with adults' attitudes toward and perceptions of science (Gauchat, 2011; Rutjens et al., 2017). Political views were measured using a seven-point Likert-type item (POLVIEWS), which asked respondents to rate their politics from extremely liberal (1) to extremely conservative (7). This variable was termed conservativism in all analyses. Respondents' religious views were measured using a similar seven-point Likert-type item (FEELREL) asking them to rate their religious beliefs from extremely non-religious (1) to extremely religious (7). This was termed religiosity. A number of studies have also illustrated racial and ethnic differences in adults' attitudes toward, and trust for, science (see Dawson, 2018; Gauchat, 2011; Makarovs, 2021). The race measure used in this study was coded silently by the interviewer as either white, black, or other (RACE). Last, research has illustrated income's positive relationship with trust in science (Gauchat, 2011) and scientific literacy (National Science Board, 2016). Income was measured as respondents' self-reported family income in thousands of U.S. dollars (INCOME).

Analysis

A conditional process analysis was conducted using generalized linear models in IBM SPSS v27 for each of the study's binary outcomes: a) too little versus too much public support for science and b) about right versus too much public support for science. The piecewise modeling sequence followed Hayes's (2018) suggestions for examining moderated mediation, a process occurring when a mediated relationship (formal education > scientific literacy > public support for science) is moderated by, or made conditional upon, another variable (SEX). The hypothesized moderated mediation process is presented in Figure 1.

For each binary outcome, four models were constructed to calculate (in order): a) the total effect of formal education on public support for science, b) the unconditional direct effect of formal education on public support for science, c) the conditional direct effect of formal education on public support for science, and c) the indirect and conditional indirect effects of formal education on public support for science through scientific literacy. Inferences were made using bootstrapped confidence intervals, except for parameters derived from the product of two coefficients (e.g., indirect effects and the index of moderated mediation). For these, inferences were made using Monte Carlo confidence intervals (see Preacher and Slig, 2012) derived from Falk and Biesanz's (2016) indirect effect confidence interval calculator. Formulas for all models, effect calculations, and their associated standard errors are as follows.

Model 1, the total effects model, used binary logistic regression with a log link function:

$$Y_1 = log\left(\frac{\pi_1}{\pi_C}\right) = i_1 + c'_1 X + \sum_{k=0}^{q} g_i C_i + e_1$$

where Y is the log odds of feeling there is too little (or about right) versus too much support for science, i is the model intercept, c is the total effect of formal education, X is formal education, C is the set of q covariates, g is the set of their associated coefficients, and e is the residual.

Model 2, the unconditional direct effects model, used binary logistic regression with a log link function:

$$Y_1 = log\left(\frac{\pi_1}{\pi_C}\right) = i_1 + c'_1 X + b_1 M + \sum_{k=0}^{q} g_i C_i + e_1$$

where c'_1 is the unconditional direct effect for education, X is education, b_1 is the coefficient for scientific literacy, and M is scientific literacy.

Model 3, the conditional direct effects model, used binary logistic regression with a log link function:

$$Y_1 = log\left(\frac{\pi_1}{\pi_C}\right) = i_1 + c'_1 X + c'_2 W + c'_3 XW$$
$$+ b_1 M + b_2 MW + \sum_{k=0}^{q} g_i C_i + e_1$$

where c'_2 is the coefficient for female, W is female, c'_3 is the coefficient for the interaction of education and female, b_1, and b_2 is the coefficient for the interaction of scientific literacy and female.

From model three, the conditional direct effect of formal education on public support for science was calculated as

$$O_{X \to Y} = c'_1 + c'_3 W$$

and the standard error for the conditional direct effect of formal education on public support was calculated as (see Aiken and West, 1991)

$$seO_{X \to Y} = \sqrt{(\text{var}(c'_1) + W^2 \text{var}(c'_3) + 2W \text{cov}(c'_1 c'_3))}$$

From model three, the conditional effect of scientific literacy on public support for science was calculated as

$$O_{M \to Y} = b_1 + b_2 W$$

and the standard error for the conditional effect of scientific literacy on public support was calculated as (see Aiken and West, 1991)

$$seO_{M \to Y} = \sqrt{(\text{var}(b_1) + W^2 \text{var}(b_2) + 2W \text{cov}(b_1 b_2))}$$

Model four, the mediator model, used linear regression with an identify link:

$$M_1 = i_1 + aX + \sum_{i=1}^{q} f_i C_i + e_1$$

where M is scientific literacy, i is the model intercept, a is the coefficient for formal education, X is formal education, C is the set of q covariates, f is the set of their associated coefficients, and e is the residual.

TABLE 3 Logistic regression models of U.S. adults' public support for science (Y_1 = too little vs too much) in 2020 and ordinary least squares model of U.S. adults' scientific literacy (M_1), n = 603.

	Model 1: Total Effect Too Little vs Too Much (Y_1)		Model 2: Direct Effect Too Little vs Too Much (Y_1)		Model 3: Conditional Direct Effect Too Little vs Too Much (Y_1)		Model 4: Component *a* Scientific Literacy (M_1)
Variable	*b* (SE)	e^b	*b* (SE)	e^b	*b* (SE)	e^b	*b* (SE)
Intercept	1.62 (.23)***	5.05	1.54 (0.24)***	4.67	1.54 (0.24)***	4.67	6.14 (0.35)***
Education	0.13 (0.04)***	1.14	0.09 (0.04)*	1.10	0.02 (0.07)	1.02	0.39 (0.03)***
Scientific literacy			0.12 (0.05)*	1.13	0.21 (0.07)**	1.23	
Age	0.00 (0.01)	1.00	0.01 (0.01)	1.01	0.01 (0.01)	1.01	−0.02 (0.01)**
Conservativism	−0.39 (0.11)**	0.68	−0.38 (0.11)**	0.68	−0.39 (0.11)**	0.68	−0.16 (0.07)*
Income	0.06 (0.05)	1.06	0.06 (0.05)	1.06	0.06 (0.05)	1.06	0.00 (0.01)
White (reference)							
Black	−0.42 (0.33)	0.66	−0.19 (0.34)	0.82	−0.20 (0.35)	0.82	−2.14 (0.29)***
Other	−0.18 (0.38)	0.84	0.03 (0.40)	1.03	0.06 (0.41)	1.06	−1.71 (0.34)***
Religiosity	−0.08 (0.10)	0.92	−0.06 (0.10)	0.94	−0.04 (0.10)	0.96	−0.17 (0.07)*
Male (reference)							
Female	0.52 (0.25)*	1.69	0.60 (0.26)*	1.82	0.56 (0.27)*	1.75	−0.66 (0.22)**
Education × Female					0.14 (0.09)	1.15	
Sci Lit × Female					−0.19 (0.09)*	0.83	

*$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

TABLE 4 Logistic regression models of U.S. adults' public support for science (Y_2 = about right vs too much) in 2020 and ordinary least squares model of U.S. adults' scientific literacy (M_2), n = 655.

	Model 1: Total Effect About Right vs Too Much (Y_2)		Model 2: Direct Effect About Right vs Too Much (Y_2)		Model 3: Conditional Direct Effect About Right vs Too Much (Y_2)		Model 4: Component *a* Scientific Literacy (M_2)
Variable	*b* (SE)	e^b	*b* (SE)	e^b	*b* (SE)	e^b	*b* (SE)
Intercept	1.80 (0.21)***	6.05	1.79 (0.21)***	5.97	1.79 (0.22)***	6.00	9.59 (0.17)***
Education	0.11 (0.04)*	1.11	0.09 (0.05)	1.09	0.01 (0.07)	1.01	0.39 (0.04)***
Scientific Literacy			0.05 (0.05)	1.05	0.12 (0.06)*	1.13	
Age	−0.00 (0.01)	1.00	−0.02 (0.01)	1.00	−0.00 (0.01)	1.00	−0.03 (0.01)***
Conservativism	−0.13 (0.10)	0.87	−0.13 (0.10)	0.88	−0.14 (0.11)	0.87	−0.17 (0.07)*
Income	0.05 (0.05)	1.05	0.05 (0.05)	1.05	0.05 (0.05)	1.05	0.03 (0.05)
White (reference)							
Black	−0.87 (0.34)*	0.42	−0.78 (0.35)*	0.46	−0.84 (0.35)*	0.43	−1.87 (0.31)***
Other	0.06 (0.37)	1.06	0.13 (0.37)	1.14	0.12 (0.38)	1.12	−1.54 (0.30)***
Religiosity	0.00 (0.11)	1.00	0.01 (0.11)	1.01	0.01 (0.11)	1.01	−0.15 (0.07)***
Male (reference)							
Female	0.37 (0.24)	1.45	0.39 (0.24)	1.48	0.41 (0.25)	1.51	−0.50 (0.21)*
Education X Female					0.15 (0.09)	1.16	
Sci Lit X Female					−0.15 (0.09)	0.86	

* $p < 0.05$, ** $p < 0.01$, and ** $p < 0.001$.

TABLE 5 Indirect effects, direct effects, and proportion mediated of formal education (X) on the log odds of feeling there is too little versus too much public support for science (Y) as mediated through scientific literacy (M), n = 603.

Type	Effect	Sex	Estimate	SE	Wald χ^2	p	95% C.I. Lower	95% C.I. Upper
Indirect (ab)	Formal Education > Scientific Literacy > Support for Science	Unconditional	0.046*	0.02	5.29	0.021	0.008	0.086[a]
		Male	0.083**	0.03	8.44	0.004	0.029	0.140[a]
		Female	0.007	0.02	0.09	0.760	−0.039	0.005[a]
Component (a, b)	Formal Education > Scientific Literacy		0.393***	0.03	128.3	<0.001	0.334	0.452
	Scientific Literacy > Support for Science	Unconditional	0.118*	0.05	5.59	0.018	0.020	0.216
		Male	0.211**	0.07	9.09	0.003	0.074	0.348
		Female	0.019	0.06	0.09	0.764	−0.099	0.137
Direct (c')	Formal Education > Support for Science	Unconditional	0.093*	0.04	4.41	.036	0.015	0.171
		Male	0.020	.07	0.08	0.777	−0.117	0.157
		Female	0.162*	0.06	6.58	0.010	0.044	0.280
Proportion mediated	P_M = ab/(c' + ab)	Unconditional	0.28	Index of −0.08ModeratedMediation(IMM)			−0.148	−0.005[a]
		Male	0.98					
		Female	0.05					

*$p < 0.05$, ** $p < 0.01$, ** $p < 0.001$, and [a]Monte Carlo CI.

From models three and four, the conditional indirect effect of formal education on public support for science through scientific literacy was defined as:

$$aO_{M\to Y} = a(b_1 + b_2 W)$$

The standard error for the conditional indirect effect was defined as (see Sobel, 1982):

$$se_{ab} = \sqrt{(a^2 se_b{}^2 + b^2 se_a{}^2 + se_a{}^2 se_b{}^2)}$$

TABLE 6 Indirect effects, direct effects, and proportion mediated of formal education (X) on the log odds of feeling there is enough versus too much public support for science (Y) as mediated through scientific literacy (M), *n* = 655.

					Wald		95% C.I.	
Type	Effect	Sex	Estimat	SE	χ^2	p	Lower	Upper
Indirect (ab)	Formal Education > Scientific Literacy > Support for Science	Unconditional	0.019	0.02	0.95	0.331	−0.016	0.056[a]
		Male	0.048*	0.02	3.85	0.050	0.001	0.097[a]
		Female	−0.010	0.03	0.11	0.740	−0.060	0.039[a]
Component (a, b)	Formal Education > Scientific Literacy		0.393***	0.04	125.4	<0.001	0.315	0.471
	Scientific Literacy > Support for Science	Unconditional	0.049	0.05	1.12	0.290	−0.042	0.140
		Male	0.122*	0.06	4.13	0.042	0.000	0.242
		Female	−0.026	0.06	0.19	0.665	−0.144	0.092
Direct (c')	Formal Education > Support for Science	Unconditional	0.087	0.05	3.70	.054	-.011	0.185
		Male	0.005	0.07	0.00	0.991	-.132	0.142
		Female	0.156*	0.06	6.06	0.014	0.038	0.274
Proportion Mediated	P_M = ab / (c' + ab)	Unconditional	0.18	Index of Moderated Mediation (IMM)		−0.058	−0.132	0.013[a]
		Male	0.91					
		Female	−0.07					

* $p < 0.05$, ** $p < 0.01$, ** $p < 0.001$, and [a]Monte Carlo CI.

The *index of moderated mediation* (Hayes, 2015) is a measure of the weight of the moderator (SEX) in the mediational pathway (formal education > scientific literacy > public support for science). It was measured as:

$$IMM = ab_2$$

Results

Complete modeling for each outcome is presented in Tables 3, 4. A summary of the indirect effects, direct effects, index of moderated mediation (IMM), and proportion mediated (P_M) for each outcome is presented in Tables 5, 6. Proportion mediated has been shown to be an unbiased measure of an indirect effect's magnitude when samples are greater than 500 (MacKinnon et al., 1995). Salient findings are discussed below for each outcome and question. When reporting logistic regression output, coefficients are exponentiated to illustrate odds ratios when possible.

Adults' formal education and public support for science

Without accounting for scientific literacy, formal education had a positive relationship with public support for science. This relationship is referred to as the total effect of formal education (Model 1). Holding background variables constant, for each year of formal education adults receive, the odds of feeling there is too little public support for science rather than too much increased by 14%, $b = 0.13$, SE = 0.04, $e^b = 1.14$, $\chi^2 = 10.56$, $p = 0.001$, 95% CI [0.05, 0.21]. Relatedly, the odds of adults feeling public support for science is just about right rather than too much increased by 11%, $b = 0.11$, SE = 0.04, $e^b = 1.11$, $\chi^2 = 6.43$, $p = 0.01$, 95% CI [0.02, 0.19]. Overall, these findings illustrate that as adults' formal education increases, so too does their likelihood of having stronger public support for science. Hypothesis 1 was confirmed.

Scientific literacy as a mediator

After accounting for scientific literacy, the relationship between formal education and public support for science attenuated in both samples: polarized ($b = 0.09$, $SE = 0.04$, $e^b = 1.10$, $\chi^2 = 5.06$, $p = 0.02$, 95% CI [0.01, 0.17]) and contiguous ($b = 0.09$, $SE = 0.05$, $e^b = 1.09$, $\chi^2 = 3.70$, $p = 0.05$, 95% CI [−0.00, 0.18]). This effect is called the unconditional direct effect of formal education (Model 2).

In both samples, education was positively associated with adults' scientific literacy (path a, Model 4), and scientific literacy had a positive relationship with adults' public support for science (path b, Model 3), albeit a non-significant one in the contiguous sample. Constructing an unconditional indirect effect from these findings (ab, see Tables 2, 5), we found that for every year of formal education, the odds of adults feeling there is too little public support for science rather than too much increased by 4.7% through education's effect on scientific literacy, which in turn affected public support for science, ab = 0.05, SE = 0.02, $e^b = 1.05$, $\chi^2 = 5.29$, $p = 0.02$, 95% CI [0.01, 0.09]. This indirect effect accounted for 28% of formal education's total effect on adults' public support for science. Similarly, for every year of formal education, the odds of feeling that support was about right rather than too much increased by 1.9% through this mediational path, ab = 0.02, SE = 0.02, $e^b = 1.02$, $\chi^2 = 0.95$, $p = 0.19$, 95% CI [−0.02, 0.06]. This accounted for 18% of the total effect of formal education in the contiguous sample. Overall, these findings illustrate that scientific literacy partially mediates the effect of formal education on public support for science: As formal education increases, so does scientific literacy, which in turn increases support for science. This effect is greater when comparing polarized positions. Hypothesis 2 was confirmed.

Gender as moderating the mediational relationship

To examine how this relationship may differ for men and women, we first calculated the conditional direct effect of formal education (Model 3)—that is, education's effect, for each gender, on public support for science after accounting for scientific literacy and background variables. For men, education was unrelated to public support for science in both samples: polarized ($c_1' = 0.02$, $SE = 0.07$, $e^b = 1.02$, $\chi^2 = 0.08$, $p > 0.05$, 95% CI [−0.12, 0.16]) and contiguous ($c_1' = 0.01$, $SE = 0.07$, $e^b = 1.01$, $\chi^2 = 0.00$, $p > 0.05$, 95% CI [−0.13, 0.14]). Yet for women, formal education was positively related in both samples. With each year of education, the odds of feeling there is too little public support for science rather than too much increased by 17.6%, ($c_1' + c_3'W) = 0.16$, $SE = 0.06$, $e^b = 1.18$, $\chi^2 = 7.29$, $p = 0.01$, 95% CI [0.04, 0.28]; and the odds of feeling it is about right rather than too much increased by 16.9%, ($c_1' + c_3'W) = 0.16$, $SE = 0.06$, $e^b = 1.17$, $\chi^2 = 6.06$, $p = 0.01$, 95% CI [0.04, 0.27].

As reported earlier, education was positively associated with adults' scientific literacy (path *a*, Model 4). However, the relationship between scientific literacy and public support for science differed by gender (Model 3). For men, scientific literacy was positively associated with public support for science in both samples: polarized ($b_1 = 0.21$, $SE = 0.07$, $e^b = 1.23$, $\chi^2 = 9.00$, $p < 0.003$, 95% CI [0.07, 0.35]) and contiguous ($b_1 = 0.12$, $SE = 0.06$, $e^b = 1.13$, $\chi^2 = 4.13$, $p = 0.04$, 95% CI [0.00, 0.24]). For women, however, there was no relationship: polarized ($(b_1 + b_2W) = .02$, $SE = 0.06$, $e^b = 1.02$, $\chi^2 = 0.11$, $p > 0.05$, 95% CI [−0.10, 0.14]), contiguous ($(b_1 + b_2W) = -0.03$, $SE = 0.06$, $e^b = 0.97$, $\chi^2 = 0.02$, $p > 0.05$, 95% CI [−0.14, 0.19]).

Constructing conditional indirect effects from these findings ($a(b_1 + b_2W)$), we found that a mediating relationship existed, but only for men. For each year of formal education a man receives, the odds of them feeling there is too little public support for science rather than too much increased by 8.7% through education's effect on scientific literacy, which in turn affected their public support for science, $a(b_1 + b_2W) = 0.08$, $SE = 0.03$, $e^b = 1.09$, $\chi^2 = 7.11$, $p = 0.008$, 95% CI [0.02, 0.14]. Similarly, the odds of them feeling that support was about right rather than too much increased by 4.9% through this mediational path, $a(b_1 + b_2W) = 0.05$, $SE = 0.02$, $e^b = 1.05$, $\chi^2 = 3.85$, $p = 0.05$, 95% CI [0.00, 0.10]. Both effects were near complete (0.98 and 0.91, respectively), suggesting the mediational pathway accounted for most of the total effect of formal education on men's public support for science. *In short, only formal education that increased men's scientific literacy increased their public support for science.*

For women, no pathway was found: polarized ($a(b_1 + b_2W) = 0.01$, $SE = 0.02$, $e^b = 1.01$, $\chi^2 = 0.12$, $p > 0.05$, 95% CI [−0.03, 0.05]) and contiguous ($a(b_1 + b_2W) = -0.01$, $SE = 0.03$, $e^b = 0.99$, $\chi^2 = 0.11$, $p > 0.05$, 95% CI [−0.06, 0.04]). The indirect effect for women was effectively zero in both samples, accounting for none of the total effect of formal education on women's' public support for science (0.05 and −0.07, respectively). *In short, formal education increased women's public support for science, regardless of its effect on scientific literacy.* Hypothesis 3 was confirmed. See Figure 2 for an illustration of these conditional effects.

Overall, the weight of gender's effect on the mediated pathway was significant in the polarized sample, illustrating that the indirect effect of formal education on public support for science through scientific literacy is smaller for women than men, IMM = −0.08, 95% CI: [−0.15, −0.01]. The weight of sex's effect on the mediated pathway in the contiguous sample was not significant, although nearly all the confidence interval was in the predicted direction, IMM = −0.06, 95% CI: [−0.13, 0.01]. Consistent with earlier findings, effects appear greater in more polarized samples.

Discussion

We aimed here first to investigate the relationship between formal education, scientific literacy, and public support for science; and then whether this relationship differed in men and women. Our results showed that formal education was positively associated with public support for science (hypothesis 1) and that this relationship was partially mediated by scientific literacy (hypothesis 2). As posited, this process was conditional on gender (hypothesis 3). For men, formal education improved public support for science only through gains in scientific literacy. For women, formal education improved public support for science regardless of gains in scientific literacy. In the ensuing discussion, we review these findings, offer potential explanations, and address implications for policy, research, and education.

Our findings support previous research showing a positive relationship between formal education and public support for science (Allum et al., 2008; Hallman, 2017; Miller et al., 1997; Muñoz et al., 2012; Sanz-Menéndez et al., 2014; National Science Board, 2014, 2020), as well as between scientific literacy and public support for science (Hallman, 2017; Sanz-Menéndez et al., 2014: Muñoz et al., 2012). Our findings also demonstrate a key assumption of the knowledge deficit model, namely that, overall, more education leads to more scientific literacy, which in turn leads to greater public support for science.

Considered alone, though, these findings ignore substantial gender differences. Specifically, the mediational process assumed by the knowledge deficit model occurred only in men. It was an inaccurate account of formal education's effect in women. This may be a principal reason why the knowledge deficit model is roundly criticized as inadequate for addressing public communication of science (Reincke et al., 2020; Simis et al., 2016). Assuming a homogenous effect for this process may lead to a model that grossly underestimates the process for men while overestimating the process for women. Indeed, our model's mediational process averaged across men and women accounted for 19–28% of the total effect of formal education, a figure that masks stark differences when considered separately: men (91–98%) and women (0–5%).

Although our design precludes us from identifying possible explanations for these differential effects, we offer several

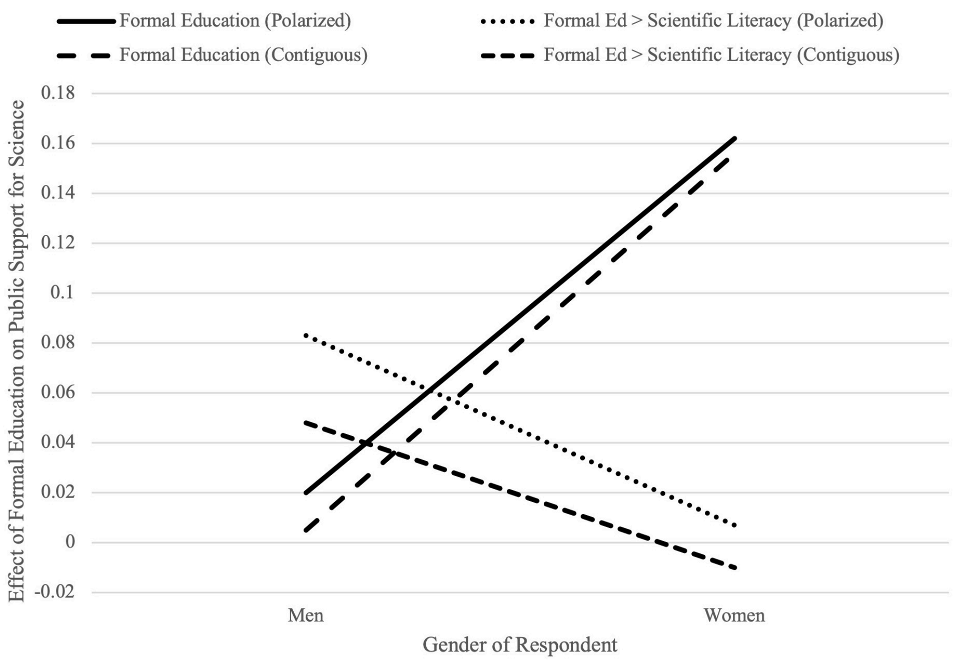

FIGURE 2
A visual representation of the condition direct effect (formal education) and the conditional indirect effect (formal education > scientific literacy) on public support for science.

conjectures here for future inquiry. Our theoretical framework, system justification theory, suggests women—historically the low-status group within science—often cope with inequalities by unconsciously supporting and justifying the social arrangements that marginalize them (Jost and Hunyady, 2002). Within the system of science, this means aligning attitudes and behaviors with what we have called the men as scientist idea. On the other hand, men, the historic high-status group, display ingroup favoritism by consciously or non-consciously working to justify their position as the perceived scientists within that system. We suspect this is a form of psychological overcompensation (Dixon et al., 1995), whereby demonstrating scientific literacy not only helps men defend science against critics, but also shows others that they deserve their privileged status. Because women lack this secondary motivation, they instead find reasons to support science without challenging its historic *status quo* or using the currency of the high-status group. Our findings support this idea. Scientific literacy was largely irrelevant to women's support for science, yet their support for science remained equal to or greater than men's both before and after accounting for scientific literacy. Others' research supports these findings, showing that women's support for science often comes more from prosocial values (Lizotte, 2020) and perceived efficacy of government programs (Schlesinger and Heldman, 2001). Women express scientific knowledge to help others learn about science, unlike men who do so to defend science against misinformation (Dudo and Besley, 2016).

Of course, it is also possible that women's positionality is secondary to more proximate causes of these differences. Our findings may simply reveal divergent epistemological tendencies in men and women. Other theories have suggested this possibility. In their landmark study of over 100 U.S. women from diverse backgrounds, Belenky et al. (1997) describe ways of knowing in women that depart from those of men. Notably, women often take positions based on experience, relationships, and subjective interpretations rather than objective facts. Measures of scientific literacy, like that used in this study, are comprised of people's ability to recall abstract scientific knowledge and deduce from general principles actions that can be applied to novel scenarios. Belenky et al. (1997) found that this is precisely the kind of knowing that is often roundly rejected by women yet embraced by men: "Many men are interested in how experience is generalized and universalized, while many women are interested in what can be learned from the particular" (p. 184). Belenky et al. (1997) further describe women with greater education as holding relativist positions that are "a far cry from the perception of science as absolute truth or as a procedure for obtaining objective facts" (p. 138). Compared to men, they argue, such women tend not to rely as readily or as exclusively on hypothetico-deductive inquiry, which posits an answer (the hypothesis) prior to data collection, as they do on examining basic assumptions and the conditions in which a problem is cast. (p. 139)

This view is also supported by our findings, which suggest women's support for science stems more from non-science learning than science learning. Whether this results from unique content in women's non-science learning or unique dispositional factors in women triggered by their non-science learning is an important question for future research.

For women, then, alternatives to the knowledge deficit model may be more fitting to explain the function of formal education in their own support for science. The dialogue model, for instance, claims that non-scientific forms of knowledge equally inform people's support for science (Reincke et al., 2020). Also known as the Public Engagement with Science (PES) model (e.g., Burchell, 2015; Schäfer et al., 2019), the dialogue model aims to increase public support for science through two-way dialogues between scientists and the public. It advocates for scientists to understand the perceptions and needs of the public and to recognize that public knowledge may be useful in scientific research (Metcalfe, 2022). Closely related is the participatory model, which recognizes citizens' power and knowledge as equal to that of scientists (Metcalfe et al., 2022). Research has shown that women who value science place greater value than men on the public's non-science knowledge. Kessler et al. (2022) and Burchell (2015) showed that women scientists more often adopt the PES model, focusing less on imparting scientific knowledge to others and more on hearing what others feel is relevant. When these findings are coupled with our own, they suggest that women see less of a disconnect between science and non-science knowledge. Women appear to use their own non-science learning to inform their support for science, and similarly value the non-science learning of others when engaging in discussions about science. Future researchers may wish to examine this claim empirically by comparing the degree to which men and women scientists value non-science knowledge and perceive its relevancy to science.

These accounts also align with empirical research showing dispositional differences in men and women relevant to how education informs their public support for science. For instance, women on average score higher on personality and aspect measures of compassion, agreeableness, openness, and neuroticism (Costa et al., 2001; Del Giudice et al., 2012; Kaiser et al., 2020; Weisberg et al., 2011). Consistent with Lizotte's (2020) claim that women base their support for government spending on concerns for other people, their higher levels of compassion, agreeableness, and openness may make them more likely to support science funding for prosocial reasons, reasons potentially illuminated through non-science learning. Further, women's higher levels of neuroticism on average may result in greater fears for the public problems science tends to address and, thus, a greater willingness to fund science. Verhulst et al. (2012) found that neuroticism was negatively related to economic conservativism and suggested that those scoring higher on neuroticism may cope with their worries by supporting social safety nets and more liberal economic policies. Non-science learning may introduce students to urgent public problems (e.g., climate change, plastic pollution, obesity, food inequality), and in doing so cause many women to support science funding as a way of mitigating their associated concerns. Our results again support this account, showing that increases in formal education, after holding scientific literacy constant, are associated with increased public support for science funding in women but not in men.

Future research may also wish to examine whether formal education contributes to these dispositional differences through socialization processes in various majors. Research has illustrated substantial gender gaps in college majors, with men more likely to study STEM fields and women more likely to study humanities, social sciences, and education fields (Speer, 2017). College preparation accounts for up to 62% of these gaps—depending on one's major— but a large portion of this variance remains unaccounted for and, according to Speer (2017), potentially explained by factors that begin acting on students well before their college years. Whether college majors marked by gender inequalities further broaden and reinforce dispositional differences is an important question for future research, one whose answer may help explain how formal education works differently for men and women to improve their support for science.

The conjectures offered here provide only some of the possible explanations for the mechanism underlying our findings. Whether the differential effects we found stem from outgroup favoritism, epistemological differences, or dispositional differences remains a question for future empirical research. Further, the degree to which this mechanism can be affected by educational policies and practices remains a question for future research. In the following section, then, we offer implications for policy and practice that seek to accommodate these differences rather than lessen them.

Implications for policy and education

Because our findings illustrate that increasing women's scientific literacy is unlikely to improve their public support for science, their implications diverge from suggestions that educators focus on closing the gender gap in science through broadening participation in STEM education (National Science Foundation, 2023; U.S. Department of Education, 2023). Still, we recognize that closing the science gender gap is a critical aim for education, meriting continuous support in research, policy, and practice. Greater diversity in science benefits everyone and is essential for ensuring science's place in the future of a well-functioning democracy.

Recent reports suggest, however, that continuous efforts to narrow the gender gap in science have been largely unsuccessful, resulting in women still comprising less than 30% of the global STEM workforce (UNESCO, 2019) and 35% of the U.S. STEM workforce (Speer, 2023). Speer describes how gifted women are lost to STEM fields before, during, and after college:

Fewer women are STEM-ready when entering college, fewer of them choose STEM majors, fewer of those stick with the STEM majors, and still fewer of those choose a STEM job after college.... These stages do not represent a weeding-out of less able students or workers. They represent a loss of well-prepared and highly qualified women to other fields. (p. 11)

Rather than maintain a focus on STEM participation then, we suggest advocates of science assume a broader view that also supports and invests in women pursuing education in non-science disciplines. Our results illustrate that increasing women's formal education, and thereby their non-science knowledge, results in greater public support for science. Adopting Chakravartty's (2023) framework, then, for women it appears that *knowledge of science* informs their support of science more so than *science knowledge*. Both Miller et al. (2022) and Achterberg et al. (2017) provide some support for this conclusion, showing that educational gains regardless of one's scientific literacy are associated with more positive attitudes and trust toward science. But because their work failed to consider differential effects, it is unclear if it underestimates this relationship in women and overestimates it in men. Our findings suggest the possibility of both. We, therefore, consider such work further support for the idea of investing equally in women's pursuits of non-science education to increase public support for science.

Supporting and investing in women pursuing education in both science and non-science disciplines means promoting collaboration and interdisciplinary learning. It means advancing non-science learning that promotes prosocial values, community, and deeper understandings of society's most pressing problems. It means a more holistic educational experience for both men and women, one that values both non-science and science learning, and works to eliminate disciplinary siloes while illustrating how seemingly disparate disciplines inform one another. By broadening the STEM focus, policymakers can stop relegating non-science learning to a secondary endeavor and marginalizing those who pursue it. We believe this is best accomplished by integrating science more clearly into the humanities, arts, and social sciences, an effort like that proposed by Wilson (1999) in his formidable work, *Consilience*, and by Meinwald and Hildebrand (2010) in their efforts to position science as a core component of liberal education. By supporting people's broad educational aims—and women's in particular—educators and policymakers can promote pro-science values and greater support for science funding. The best approach, it seems, may be simply to communicate science's value to all, while opening pathways to those who choose to understand it better.

Delimitations and limitations

Any interpretation of this study's findings should be made with an understanding of four of its delimitations and limitations. First, this study focused on U.S. adults. Its findings were not intended to generalize beyond the U.S., so readers are cautioned to consider other countries' cultural differences and similarities before applying these findings internationally. Better still, researchers may wish to replicate this study internationally to determine whether its findings apply to another country's adults specifically. Second, although the measure of scientific literacy used in this study is well established in social science research (e.g., Allum et al., 2018; Gauchat, 2012; Makarovs, 2021; Tourgangeau et al., 2016), there are wide ranging operationalizations of scientific literacy in the literature. Our measure focused on an adult's understanding of basic science facts and scientific processes (i.e., probability and experimental design). As we discussed earlier, other measures may target additional competencies and knowledge that may or may not be relevant to this study's findings. Third, our dependent variable, public support for science, focused on a person's support for public spending on science. Many people may support scientific epistemology or practice but prefer that public funds be allocated toward meeting citizens' basic needs, especially during economic or public health crises. This measure, therefore, may be best viewed as a measure of support for publicly funded scientific research, not necessarily support for science itself. Last, the 2018 General Social Survey (GSS) dataset used here was collected before the COVID-19 epidemic, which may have in turn affected adults' views on science. The GSS is a cross-sectional dataset, meaning it is designed to provide an understanding of the U.S. public's attitudes and behaviors at a specific point in time. At the time of this writing, a post-pandemic GSS dataset had yet to be released. When it is, future researchers should consider if and how the processes identified here may have changed in response to the COVID-19 pandemic.

Conclusion

This study illustrates the degree to which scientific literacy functions as a mechanism for formal education's effects on public support for science. In doing so, it also highlights substantive differences in this process for men and women. Several primary conclusions may be drawn. First, although at first glance the knowledge deficit model appears to offer some direction for guiding educational policy and practice in the general U.S. adult population, it is not a comprehensive model for all adults. The model appears to only depict men's educational processes, not women's. Any use of it, therefore, should occur with this in mind. Second, men and women use formal education and scientific literacy differently to develop support for science. Men who support science appear to use their formal education to develop scientific literacy, and this scientific literacy becomes essential to their support. Women who support science, however, appear to use their formal education as well, but for them what informs their support are educational gains unrelated to scientific literacy. When attempting to develop public support for science, then, educational policies and practices should encourage both science and non-science learning rather than just STEM learning. Inclusive and effective practices must account for the differences in how men and women use education to develop their support for science. Last, system justification theory offers one explanation for the mechanism behind these differences. For men, gaining and illustrating scientific literacy is a form of ingroup favoritism, a way to maintain and justify their historic high status within science. For women, supporting science through other means is a form of outgroup favoritism, a way to avoid challenging science's historic *status quo* while meeting their own needs for certainty, security, and social conformity.

But perhaps most importantly, we feel this study serves to remind all stakeholders of the importance of recognizing the unique ways in which men and women engage with and support public funding of science. By accounting for these differences and tailoring educational policies and practices accordingly, we can work toward a more inclusive, effective, and dynamic scientific landscape that fosters curiosity, critical thinking, and enthusiasm for science as a public endeavor among all members of society.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://gss.norc.org/us/en/gss/get-the-data.html.

Ethics statement

The studies involving humans were approved by University of Arkansas Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

KR: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Software, Supervision, Writing – original draft, Writing – review and editing. AG: Writing – original draft, Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Achterberg, P., de Koster, W., and van der Waal, J. (2017). A science confidence gap: Education, trust in scientific methods, and trust in scientific institutions in the United States, 2014. *Public Underst. Sci.* 26, 704–720. doi: 10.1177/0963662515617367

Aiken, L. S., and West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage Publications, Inc.

Algara, C., Fuller, S., and Hare, C. (2020). The conditional effects of scientific knowledge and gender on support for COVID-19 government containment policies in partisan America. *Polit. Gender* 16, 1–10. doi: 10.1017/S1743923X20000458

Allum, N., Besley, J., Gomez, L., and Brunton-Smith, I. (2018). Disparities in science literacy: Cognitive and socioeconomic factors don't fully explain the gaps. *Science* 360, 861–862. doi: 10.1126/science.aar8480

Allum, N., Strugis, P., and Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. *Public Underst. Sci.* 17, 35–54. doi: 10.1177/0963662506070159

Bak, H. J. (2001). Education and public attitudes toward science: Implications of the "deficit model" of education and support for science and technology. *Soc. Sci. Quar.* 82, 779–795. doi: 10.1111/0038-4941.00059

BEIS, and Department for Business, Energy and Industrial Society (2020). *Public attitudes to science, 2019. (Research Paper: 2020/012)*. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905466/public-attitudes-to-science-2019.pdf (accessed March 17, 2023).

Belenky, M. F., McVicker-Clinchy, B., Goldberger, N. R., and Tarule, J. M. (1997). *Women's ways of knowing: The development of self, voice, and mind*, 2nd Edn. New York, NY: Basic Books.

Beveridge, A. A. (2007). "The general social survey and its impact in sociology and other social sciences," in *The General Social Survey (GSS) the next decade and beyond*, eds P. White and F. Scioli (Alexandria, VA: National Science Foundation), 24–26.

Bruckermann, T., Greving, H., Schumann, A., Stillfried, M., Börner, K., Kimmig, S. E., et al. (2023). Scientific reasoning skills predict topic-specific knowledge after participation in a citizen science project on urban wildlife ecology. *J. Res. Sci. Teach.* 60, 1915–1941. doi: 10.1002/tea.21835

Burchell, K. (2015). *Factors affecting public engagement by researchers: Literature review*. Ethiopia: Policy Studies Institute.

Card, D., DellaVigna, S., Funk, P., and Iriberri, N. (2022). Gender gaps at the academies. *Natl. Bureau Econ. Res.* 120: e2212421120. doi: 10.3386/w30510

Carli, L. L., Alawa, L., Lee, Y., Zhao, B., and Kim, E. (2016). Stereotypes about gender and science: Women ≠ scientists. *Psychol. Women Quar.* 40, 244–260. doi: 10.1177/0361684315622645

Cassese, E. C., Farhart, C. E., and Miller, J. M. (2020). Gender differences in COVID-19 conspiracy theory beliefs. *Polit. Gender* 16, 1009–1018. doi: 10.1017/S1743923X20000409

Causey, J., Gardner, A., Pevitz, A., Ryu, M., and Shapiro, D. (2023). *Some college, no credential student outcomes: Annual Progress Report – Academic Year 2021/22*. Herndon, VA: National Student Clearinghouse Research Center.

Chakravartty, A. (2023). Scientific knowledge vs. knowledge of science. *Sci. Educ.* 32, 1795–1812. doi: 10.1007/s11191-022-00376-6

Charlesworth, T. E. S., and Banaji, M. R. (2019). Gender in science, technology, engineering, and mathematics: Issues, causes, solutions. *J. Neurosci.* 39, 7228–7243. doi: 10.1523/JNEUROSCI.0475-18.2019

Costa, P. T., Terracciano, A., and McCrae, R. R. (2001). Gender differences in personality traits across cultures: Robust and surprising findings. *J. Personal. Soc. Psychol.* 81, 322–331. doi: 10.1037/0022-3514.81.2.322

Dawson, E. (2018). Reimagining publics and (non) participation: Exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. *Public Underst. Sci.* 27, 772–786. doi: 10.1177/0963662517750072

Del Giudice, M., Booth, T., and Irwing, P. (2012). The distance between Mars and Venus: Measuring global sex differences in personality. *PLoS One* 7:e29265. doi: 10.1371/journal.pone.0029265

Diekman, A. B., Clark, E. K., Johnston, A. M., Brown, E. R., and Steinberg, M. (2011). Malleability in communal goals and beliefs influences attraction to STEM careers: Evidence for a goal congruity perspective. *J. Personal. Soc. Psychol.* 101, 902–918. doi: 10.1037/a0025199

Dixon, R. A., Backman, L. B., and Backman, L. (1995). *Compensating for psychological deficits and declines: Managing losses and promoting gains*. Hove: Psychological Press.

Dolgin, E. (2021). The tangled history of mRNA vaccines. *Nature* 597, 318–324. doi: 10.1038/d41586-021-02483-w

Dudo, A., and Besley, J. C. (2016). Scientists' prioritization of communication objectives for public engagement. *PLoS One* 11:e0148867. doi: 10.1371/journal.pone.0148867

Erduran, S., and Dagher, Z. R. (2014). "Science as a social-institutional system," in *Reconceptualizing the nature of science for science education. contemporary trends and issues in science education*. Berlin: Springer. doi: 10.1007/978-94-017-9057-4_7

Falk, C. F., and Biesanz, J. C. (2016). Two cross-platform programs for inferences and interval estimation about indirect effects in mediational models. *SAGE Open* 6. doi: 10.1177/2158244015625445

Florio, M., Giffoni, F., and Catalano, G. (2020). Should governments fund basic science? Evidence from a willingness-to-pay experiment in five universities. *J. Econ. Pol. Reform* 23, 16–33. doi: 10.1080/17487870.2018.1547638

Gauchat, G. (2011). The cultural authority of science: Public trust and acceptance of organized science. *Public Underst. Sci.* 20, 751–770. doi: 10.1177/0963662510365246

Gauchat, G. (2012). Politicization of science in the public sphere: A study of public trust in the United States, 1974 to 2010. *Am. Sociol. Rev.* 77, 167–187. doi: 10.1177/0003122412438225

Gauchat, G. (2015). The political context of science in the United States: Public acceptance of evidence-based policy and science funding. *Soc. Forces* 94, 723–746. doi: 10.1093/sf/sov040

Gericke, N., and Mc Ewen, B. (2023). Defining epigenetic literacy: How to integrate epigenetics into the biology curriculum. *J. Res. Sci. Teach.* 60, 2216–2254. doi: 10.1002/tea.21856

Giffoni, F., and Florio, M. (2023). Public support of science: A contingent valuation study of citizens' attitudes about CERN with and without information about implicit taxes. *Res. Pol.* 52, 1–19. doi: 10.1016/j.respol.2022.104627

Goldfarb, J. L., and Kriner, D. L. (2017). Building public support for science spending: Misinformation, motivated reasoning, and the power of corrections. *Sci. Commun.* 39, 77–100. doi: 10.1177/1075547016688325

GSS (2021). *50 years of the general social survey*. Chicago, IL: NORC at the University of Chicago.

Hallman, W. K. (2017). "What the public thinks and knows about science and why it matters," in *The oxford handbook of the science of science communication*, eds K. H. Jamieson, D. Kahan, and D. A. Scheufele (Oxford: Oxford University Press), 61–72.

Hamilton, L. C. (2008). Who cares about polar regions? Results from a survey of U.S. public opinion. *Artic Antarctic Alpine Res.* 40, 671–678. doi: 10.1657/1523-0430(07-105)[HAMILTON]2.0.CO;2

Hamilton, L. C. (2011). Education, politics and opinions about climate change evidence for interaction effects. *Climate Change* 104, 231–242. doi: 10.1007/s10584-010-9957-8

Hamilton, L. C., Cutler, M. J., and Schaefer, A. (2012). Public knowledge and concern about polar-region warming. *Polar Geography* 35, 155–168. doi: 10.1080/1088937X.2012.684155

Hayes, A. F. (2015). An index and test of linear moderated mediation. *Multivariate Behav. Res.* 50, 1–22. doi: 10.1080/00273171.2014.962683

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis*, 2nd Edn. New York, NY: Guilford.

Hayes, B. C., and Tariq, V. N. (2000). Gender differences in scientific knowledge and attitudes toward science: A comparative study of four Anglo-American nations. *Public Underst. Sci.* 9, 433–447. doi: 10.1088/0963-6625/9/4/306

Huang, J., Gate, A. J., Sinatra, R., and Barabási, A. L. (2020). Historical comparison of gender inequality in scientific careers across countries and disciplines. *PNAS* 117, 4609–4616. doi: 10.1073/pnas.1914221117

Jost, J. T. (2019). A quarter century of system justification theory: Questions, answers, criticisms, and societal applications. *Br. J. Soc. Psychol.* 58, 263–314. doi: 10.1111/bjso.12297

Jost, J. T. (2020). *A theory of system justification*. Cambridge, MA: Harvard University Press.

Jost, J. T., and Banaji, M. R. (1994). The role of stereotyping in system-justification and the production of false consciousness. *Br. J. Soc. Psychol.* 33, 1–27. doi: 10.1111/j.2044-8309.1994.tb01008.x

Jost, J. T., and Hunyady, O. (2002). The psychology of system justification and the palliative function of ideology. *Eur. Rev. Soc. Psychol.* 13, 111–153. doi: 10.1080/10463280240000046

Jost, J. T., Banaji, M. R., and Nosek, B. A. (2004). A decade of system justification theory: Accumulated evidence of conscious and unconscious bolstering of the status quo. *Polit. Psychol.* 25, 823–989. doi: 10.1111/j.1467-9221.2004.00402.x

Kahn, M. S. (2020). Paid family leave and children health outcomes in OECD countries. *Child Youth Serv. Rev.* 116:105259. doi: 10.1016/j.childyouth.2020.105259

Kaiser, T., Del Giudice, M., and Booth, T. (2020). Global sex differences in personality: Replication with an open online dataset. *J. Personal.* 88, 415–429. doi: 10.1111/jopy.12500

Kampa, N., and Koeller, O. (2016). German national proficiency scales in biology: Internal structure, relations to general cognitive abilities and verbal skills. *Sci. Educ.* 100, 903–922. doi: 10.1002/sce.21227

Kennedy, B., and Hefferon, M. (2019). *What Americans know about science: Science knowledge levels remain strongly tied to education: Republican and Democrats are about equally knowledgeable*. Washington, D.C: Pew Research Center.

Kerkhoven, A. H., Russo, P., Land-Zandstra, A. M., Saxena, A., and Rodenburg, F. J. (2016). Gender stereotypes in science education resources: A visual content analysis. *PLoS One* 11:e0165037. doi: 10.1371/journal.pone.0165037

Kessler, S. H., Schäfer, M. S., Johann, D., and Rauhut, H. (2022). Mapping mental models of science communication: How academics in Germany, Austria and Switzerland understand and practice science communication. *Public Underst. Sci.* 31, 711–731. doi: 10.1177/09636625211065743

Kray, L. J., Howland, L., Russell, A. G., and Jackman, L. M. (2017). The effects of implicit gender role theories on gender system justification: Fixed beliefs strengthen masculinity to preserve the status quo. *J. Personal. Soc. Psychol.* 112, 98–115. doi: 10.1037/pspp0000124

Lau, K. C. (2009). A critical examination of PISA's assessment on scientific literacy. *Int. J. Sci. Math. Educ.* 7:1061. doi: 10.1007/s10763-009-9154-2

Lau, W. W. Y., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J., et al. (2020). Evaluating scenarios toward zero plastic pollution. *Science* 369, 1455–1461. doi: 10.1126/science.aba9475

Le Hebel, F., Montpied, P., and Tiberghien, A. (2014). "Which effective competencies do students use in PISA assessment of scientific literacy?," in *ESERA 2011 selected contributions. Topics and trends in current science education*, eds C. Bruguière, A. Tiberghien, and P. Clément (Dordrecht: Springer), 273–289. doi: 10.1007/978-94-007-7281-6_17

Lee, C. (2019). *Not so basic research: The unrecognized importance of fundamental scientific discoveries*. Washington, DC: Science in the News.

Liou, P.-Y. (2021). Students' attitudes toward science and science achievement: An analysis of the differential effects of science instructional practices. *J. Res. Sci. Teach.* 58, 310–334. doi: 10.1002/tea.21643

Lizotte, M. K. (2020). *Gender differences in public opinion: Values and political consequences*. Philadelphia, PA: Temple University Press.

MacKinnon, D. P., Warsi, G., and Dwyer, J. H. (1995). A simulation study of mediated effect measures. *Multivariate Behav. Res.* 30, 41–62. doi: 10.1207/s15327906mbr3001_3

Madigan, J. C. (2009). The education of women and girls in the United States: A historical perspective. *Adv. Gender Educ.* 1, 11–13.

Makarovs, K. (2021). *Examining disparities in public support for, knowledge about, and trust in science*. Doctoral thesis, The University of Essex Research Repository, The University of Essex: Colchester.

Mascret, N., and Cury, F. (2015). I'm not scientifically gifted, I'm a girl: Implicit measures of gender-science stereotypes – preliminary evidence. *Educ. Stud.* 41, 462–465. doi: 10.1080/03055698.2015.1043979

Meinwald, J., and Hildebrand, J. G. (2010). *Science and educated American: A core component of liberal education*. Cambridge, MA: Academy of Arts and Sciences.

Metcalfe, J. (2022). Science communication: A messy conundrum of practice, research and theory. *JCOM* 21:C07. doi: 10.22323/2.21070307

Metcalfe, J., Gascoigne, T., Medvecky, F., and Nepote, A. C. (2022). Participatory science communication for transformation. *JCOM* 21:E. doi: 10.22323/2.21020501

Miller, J. D. (2015). "The conceptualization and measurement of civic scientific literacy for the twenty-first century," in *Science and the educated American: A core component of liberal education*, eds J. Meinwald and J. G. Hildebrand (Cambridge, MA: American Academy of Arts and Sciences), 241–255.

Miller, J. D. (2022). Public understanding of science and technology in the Internet era. *Public Underst. Sci.* 31, 266–272. doi: 10.1177/09636625211073485

Miller, J. D., Ackerman, M. S., Laspra, B., Polino, C., and Huffaker, J. S. (2022). Public assessment of the Trump administration's handling of the Covid pandemic: A case study in lifelong learning. *Int. J. Lifelong Educ.* 41, 493–512. doi: 10.1080/02601370.2022.2118381

Miller, J. D., Pardo, R., and Niwa, F. (1997). *Public perceptions of science and technology: A comparative study of the European Union, the United States, Japan, and Canada*. Chicago, IL: Chicago Academy of Sciences.

Motta, M. (2019). Explaining science funding attitudes in the United States: The case for science interest. *Public Underst. Sci.* 28, 161–176. doi: 10.1177/0963662518795397

Muñoz, A., Moreno, C., and Luján, J. L. (2012). Who is willing to pay for science? On the relationship between public perception of science and the attitude to public funding of science. *Public Underst. Sci.* 21, 242–253. doi: 10.1177/0963662510373813

National Academies of Sciences, Engineering, and Medicine (2016). *Science literacy: Concepts, contexts, and consequences*. Washington, D.C: The National Academies Press.

National Center for Science and Engineering Statistics (2023). *Diversity and STEM: Women, minorities, and persons with disabilities 2023. special report NSF 23-315*. Alexandria, VA: National Science Foundation.

National Research Council (1996). *National science education standards*. Washington, D.C: The National Academies Press.

National Science Board (2014). *Science and engineering indicators 2014 (NSB 14-01)*. Alexandria, VA: National Science Foundation.

National Science Board (2016). *Science and engineering indicators, 2016*. Alexandria, VA: National Science Foundation.

National Science Board (2018). *Science and engineering indicators 2018 (NSB-2018-1)*. Alexandria, VA: National Science Foundation.

National Science Board (2020). *Science and technology: Public attitudes, knowledge, and interest. science and engineering indicators 2020 (NSB-2020-7)*. Alexandria, VA: National Science Board.

National Science Foundation (2023). *Broadening participation in STEM*. Alexandria, VA: National Science Foundation.

Nentwig, P., Roennebeck, S., Schoeps, K., Rumann, S., and Carstensen, C. (2009). Performance and levels of contextualization in a selection of OECD countries in PISA 2006. *J. Res. Sci. Teach.* 46, 897–908. doi: 10.1002/tea.20338

Norris, S. P., and Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Sci. Educ.* 87, 224–240. doi: 10.1002/sce.10066

OECD (2016). *PISA 2015 assessment and analytical framework: Science, reading, mathematic and financial literacy*. Paris: OECD Publishing.

OECD (2017a). *How does PISA for development measure scientific literacy? PISA for development brief 10*. Paris: OECD Publishing.

OECD (2017b). *PISA 2015 assessment and analytical framework: Science, reading, mathematic, financial literacy and collaborative problem solving*. Paris: OECD Publishing.

Pamuk, Z. (2021). *Politics and expertise: How to use science in a democratic society*. Princeton, NJ: Princeton University Press.

Preacher, K. J., and Slig, J. P. (2012). Advantages of monte carlo confidence intervals for indirect effects. *Commun. Methods Measures* 6, 77–98. doi: 10.1080/19312458.2012.679848

Reincke, C. M., Bredenoord, A. L., and van Mil, M. H. (2020). From deficit to dialogue in science communication: The dialogue communication model requires additional roles from scientists. *EMBO Rep.* 21:e51278. doi: 10.15252/embr.202051278

Rekker, R. (2021). The nature and origins of political polarization over science. *Public Underst. Sci.* 30, 352–368. doi: 10.1177/0963662521989193

Rudolph, J. L. (2024). Scientific literacy: Its real origin story and functional role in American education. *J. Res. Sci. Teach.* 61, 519–532. doi: 10.1002/tea.21890

Rutjens, B. T., Sutton, R. M., and van der Lee, R. (2017). Not all skepticism is equal: Exploring the ideological antecedents of science acceptance and rejection. *Pers. Soc. Psychol. Bull.* 44, 384–405. doi: 10.1177/0146167217741314

Saad, L. (2022). *U.S. political ideology steady; conservatives, moderates tie*. Washington, D.C: Gallup.

Sanz-Menéndez, L., Van Ryzin, G. G., and del Pino, E. (2014). Citizens' support for government spending on science and technology. *Sci. Public Policy* 41, 611–624. doi: 10.1093/scipol/sct091

Schäfer, M. S., Kessler, S. H., and Fähnrich, B. (2019). "Analyzing science communication through the lens of communication science: Reviewing the empirical evidence," in *Handbooks of communication science. science communication*, eds A. Leßmöllmann, M. Dascal, and T. Gloning (Berlin: De Gruyter).

Schlesinger, M., and Heldman, C. (2001). Gender gap or gender gaps? New perspectives on support for government action and policies. *J. Polit.* 63, 59–92. doi: 10.1111/0022-3816.00059

She, H.-C., Lin, H.-S., and Huang, L.-Y. (2019). Reflections on and implications of the Programme for International Student Assessment 2015 (PISA 2015) performance of students in Taiwan: The role of epistemic beliefs about science in scientific literacy. *J. Res. Sci. Teach.* 56, 1309–1340. doi: 10.1002/tea.21553

Simis, M. J., Madden, H., Cacciatore, M. A., and Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication? *Public Underst. Sci.* 25, 400–414. doi: 10.1177/0963662516629749

Sobel, M. E. (1982). "Asymptotic confidence intervals for indirect effects in structural equation models," in *Sociological methodology*, ed. S. Leinhart (San Francisco, CA: Jossey-Bass), 290–312.

Speer, J. D. (2017). The gender gap in college major: Revisiting the erole of pre-college factors. *Lab. Econ.* 44, 69–88. doi: 10.1016/j.labeco.2016.12.004

Speer, J. D. (2023). Bye bye Ms. American Sci: Women and the leaky STEM pipeline. *Econ. Educ. Rev.* 93, 1–15. doi: 10.1016/j.econedurev.2023.102371

Steel, B. S., Warner, R. L., and Lach, D. (2010). Gender differences in support for scientific involvement in U.S. environmental policy. *Sci. Technol. Hum. Values* 35, 147–173. doi: 10.1177/0162243909340

Stoet, G., and Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics. *Psychol. Sci.* 29:0956797617741719. doi: 10.1177/0956797617741719

Teig, N., Scherer, R., and Kjærnsli, M. (2020). Identifying patterns of students' performance on simulated inquiry tasks using PISA 2015 log-file data. *J. Res. Sci. Teach.* 57, d1400–d1429. doi: 10.1002/tea.21657

Tourgangeau, R., Maitland, A., and Yan, H. Y. (2016). Assessing the scientific knowledge of the general public: The effects of question format and encouraging or discouraging don't know responses. *Public Opin. Quar.* 80, 741–760. doi: 10.1093/poq/nfw009

U.S. Department of Education (2023). *Science, technology, engineering, and math, including computer science*. Washington, D.C: U.S. Department of Education.

UNESCO (2012). *International standard classification of education, ISCED 2011*. Paris: UNESCO Institute for Statistics.

UNESCO (2019). *Women in science [Fact sheet no. 55]*. Paris: UNESCO Institute for Statistics.

Verhulst, B., Eaves, L. J., and Hatemi, P. K. (2012). Correlation not causation: The relationship between personality traits and political ideologies. *Am. J. Polit. Sci.* 56, 34–51. doi: 10.1111/j.1540-5907.2011.00568.x

Weisberg, Y. J., DeYoung, C. G., and Hirsh, J. B. (2011). Gender differences in personality across the ten aspects of the Big Five. *Front. Psychol.* 2:178. doi: 10.3389/fpsyg.2011.00178

Whitman-Cobb, W. N. (2020). Stubborn stereotypes: Exploring the gender gap in support for space. *Space Policy* 54:101390. doi: 10.1016/j.spacepol.2020.101390

Wilson, E. O. (1999). *Consilience: The unity of knowledge*. New York, NY: Vintage Books.

Woolston, C., and Ong, S. (2022). Three scientists at the cutting edge of new energy solutions. *Nature* 609, S14–S15. doi: 10.1038/d41586-022-02835-0

Yin, Y., Dong, Y., Wang, K., Wang, D., and Jones, B. F. (2022). Public use and public funding of science. *Nat. Hum. Behav.* 6, 1344–1350. doi: 10.1038/s41562-022-01397-5