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Epistemic engagement: examining personal epistemology and engagement preferences with climate change in Oregon

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Abstract
Engaging politically polarized publics surrounding climate science is a vital element in the effort to enact climate mitigation policy. Science communication experts have identified several models of public engagement with science, including the deficit, dialogue, participation, and lay expertise model. Existing research suggests that the deficit model in particular is a largely ineffective model of engagement for controversial science like climate change. There is very little research, however, regarding the engagement preferences of political groups, or how those preferences differ. This study assesses preferences for climate change engagement in the state of Oregon in the United States and examines the relationship between those preferences and epistemic beliefs about climate science. Overall, we find that liberals are significantly more likely than moderates or conservatives to view climate science as certain and simple and to rely on expert knowledge more than their own direct experience. By contrast, conservatives are significantly more likely than liberals or moderates to view climate science as uncertain and complex and to rely on their own direct experience over the knowledge of content experts. We also find that perceived certainty and simplicity are positive predictors of a preference for the deficit model of science communication. Implications for public engagement with climate change and suggestions for future research are discussed.

Keywords Public engagement · Climate change · Personal epistemology

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1 Introduction

Effectively engaging publics with climate science is vital in order to motivate climate change mitigation policy. Science communication scholars have identified four models of public engagement: the deficit model, the dialogue model, the participation model, and the lay expertise model. Engaging publics within the United States about climate change utilizing any of these models can be incredibly difficult, as climate change is politically polarized, and deficit model tactics in particular have been shown to be largely ineffective. There is very little research, however, regarding the engagement preferences of liberals, moderates, and conservatives and, more importantly, how those preferences may differ and why. This study combines literature in science communication on models of public engagement and literature in philosophy on personal epistemology to examine engagement preferences for climate change engagement in the state of Oregon in the United States. Specifically, we compare the engagement preferences and epistemic beliefs of liberals, moderates, and conservatives, and we examine the relationship between engagement preferences and epistemic beliefs. Overall, we find that liberals are significantly more likely than moderates or conservatives to view climate science as epistemically certain (i.e., objectively true) and less epistemically complex (i.e., universal across contexts) and to rely on expert knowledge more than their own direct experience. By contrast, conservatives are significantly more likely than liberals or moderates to view climate science as uncertain (i.e., having epistemic variability) and complex (i.e., context dependent) and to rely on their own direct experience over the knowledge of content experts.

1.1 Public engagement with science

Scholars in science communication and public engagement have identified four models of public engagement with science that address the relationship between scientists and lay publics[1]: deficit, dialogue, participation, and lay expertise. While not mutually exclusive, each model is unique in the assumed role of scientists and lay audiences in communication interactions. The *deficit model* refers to one-way communication where knowledge and information is communicated from experts to lay publics with little to no feedback (Miller 2010; Suldovsky 2016). The *dialogue model* embraces a two-way model of engagement where experts and lay publics engage in dialogue with one another; in this model, lay publics are invited to ask questions and give scientists feedback (van der Sanden and Meijman 2008). The *participation* model takes the feedback mechanism one step further and allows publics to express their perspectives on the implications and directions of scientific research and exert some level of control regarding whether and how that research is utilized (Cameron and Deslandes 2011). The participation model is often used within the context of public policy (Bell 2008) or for emerging technologies, like nanotechnology, where public input is sought prior to significant research and development (Pidgeon and Rogers-Hayden 2007). The *lay expertise* model is somewhat similar to the participation model in that it aims to integrate scientific and lay perspectives. However, the lay expertise model is unique in that it aims to prioritize nonscientific ways of knowing and integrate that with scientific perspectives (Prior

[1] Importantly, these models of public engagement with science focus exclusively on the relationship between scientists and lay publics. These models do not aim to capture the broad and heterogeneous science communication environment that exists beyond these two groups.

2003). Lay expertise is often utilized within sustainability science and other transdisciplinary efforts that treat science as *one* method of knowing about the world among many (equally legitimate) methods (e.g., Suldovsky, McGreavy, & Lindenfeld, 2018).

Examining when, how, and for whom these models are effective is one of the central research aims of science communication (Engineering National Academies of Sciences 2016). Some of the current work in this arena aims to understand, for example, why the deficit model is still heavily utilized despite being shown to be largely ineffective (Ko 2016; Simis et al. 2016), the ways in which the models function "on the ground" including the challenges faced by communicators (Suldovsky et al. 2018), and how efforts to engage publics might be falling short (Dawson 2014). Clearly, not all public engagement efforts are suitable for every context and with every public. Designing effective public engagement strategies for controversial science topics specifically, like climate change, can be particularly challenging, as public perception of controversial science is often shaped by psychological and sociocultural factors that go beyond merely having access to and understanding scientific data.

Research on public perception of climate change, for example, has demonstrated that climate change beliefs and policy preferences are influenced by factors other than climate change knowledge or education level, including value commitments (Leiserowitz 2006; Nilsson et al. 2004), social norms (Nilsson et al. 2004), and political beliefs (Whitmarsh 2011). Among these variables, political partisanship and ideology serve as the most powerful predictors of climate change beliefs, such that liberals and Democrats are more likely to accept climate science and support policy action than conservatives and Republicans (Egan and Mullin 2017). These political identities act a sort of perceptual filter through which people understand and make judgments about climate science (Egan and Mullin 2017; Kahan et al. 2012). Political ideology and political party membership are distinct attributes; however, research demonstrates that the relationship between the two is becoming stronger over time (Abramowitz and Saunders 2006). While political identities have been shown to be the most significant predictor of climate change beliefs, other variables (e.g., anti-intellectualism) have been shown to be a driving force behind the rejections of scientific consensus (Merkley 2020). The central question for science communication researchers and practitioners, then, is: how can we design and implement effective public engagement strategies for controversial science topics like climate change?

We echo other research in stakeholder engagement for environmental issues (Kaplowitz and Lupi 2012; Strager and Rosenberger 2006; D. Whitmarsh and Palmieri 2009) and propose that assessing public preferences for engagement ought to be a central consideration for science communication scholars and practitioners when designing and evaluating public engagement with science strategies. Importantly, merely complying with public preferences for engagement is certainly not a guarantee of engagement success; however "success" may be defined. In order to support sophisticated applications of public engagement strategies, understanding the variables that may predict model preferences, processes, and outcomes is vital. More importantly, understanding these variables may aid us in evaluating why and with whom the use of these models is effective and with whom they may fail.

1.2 Epistemic beliefs and models of engagement

One factor that may influence why particular models of science communication are preferred and what makes them more or less effective is communicators' epistemic beliefs (Suldovsky 2016; Suldovsky et al. 2017, 2018). Assumptions about the nature of scientific knowledge is

arguably imbedded within the models of public engagement with science, as the models incrementally move from significant epistemic division between scientists and lay publics to very little epistemic separation. The deficit model assumes the most epistemic authority of science compared to the other models such that knowledge and information are produced by scientists and handed down to those not equipped or able to produce that knowledge. The dialogue model maintains similar epistemic separation to the deficit model yet affords lay publics the opportunity to talk with experts and, to some extent, offer their perspective. The participation model assumes less epistemic separation between scientists and publics than the deficit or dialogue model in that it gives the public control over the directions and implications of scientific research. However, it still maintains the epistemic authority of science, as it privileges scientific ways of knowing and merely invites lay publics to provide input regarding the directions and applications of that knowledge. The lay expertise model, by contrast, levels the epistemic playing field in that it assumes scientists and lay publics both have knowledge about the world that ought to be equally valued and given equal consideration in our ongoing efforts to produce knowledge about the world.

Previous work has explored the relationship between epistemic beliefs and science communication. Studies have examined, for example, how philosophical beliefs, including epistemic assumptions, affect cross-disciplinary collaboration and communication among scientific experts (Eigenbrode et al. 2007; O'Rourke et al. 2014). This work has found that explicit discussion among research teams regarding researchers' epistemic beliefs (particularly their motivation for producing knowledge, the methods they utilize and trust to make knowledge claims, and the level of evidence required to make those claims) increases team cohesion and improves cross-disciplinary communication. Another work has shown that scientists' conception of stakeholder expertise is related to how they engage with stakeholder partners, such that the more the scientists view the stakeholder's expertise as similar to their own, the more likely they are to engage in participative models of engagement (Suldovsky et al. 2017).

Epistemic beliefs have also been examined in relation to political ideology. For example, work within the field of psychology has explored the epistemic differences between liberals and conservatives, focusing mostly on how epistemic beliefs and needs attract someone to a given political ideology (e.g., Jost, Kruglanski, & Simon, 2013). This research shows that those who are attracted to conservative ideologies typically have an epistemic motivation to reduce epistemic uncertainty and complexity. That is, political conservatives prefer epistemic certainty and structure and seek out cognitive closure (Jost et al. 2009). Another work has shown that the need for cognitive closure can be amplified for conservatives when an issue is framed within the context of liberal ideological considerations (Federico et al. 2012). This body of literature also shows that these epistemic dispositions relate to other political attitudes, including anti-immigrant attitudes and nationalism (Chirumbolo et al. 2004), in-group favoritism, and a rejection of deviates (Kruglanski et al. 2006).

The current study builds off of these efforts. Following other works examining the philosophical underpinnings of political ideologies and science communication, we contend that concepts within epistemology have something significant to offer science communication researchers in their quest to better understand the models of public engagement and improve when, why, and how those models should be utilized by public engagement practitioners. Rather than focusing on scientists' epistemic assumptions or the relationship between generalized epistemic beliefs (e.g., the "need for cognitive closure") and political ideology, the current study focuses on lay publics' epistemic views and engagement preferences surrounding climate change. To that end, we turn to literature in personal epistemology.

1.3 Personal epistemology

Epistemology as a philosophical enterprise deals with the conditions for what counts as knowledge, including the necessary sources, structure, and limits of that knowledge (Steup 2018). Outside of the critical examination and purposeful study of knowledge as is done in philosophy, individuals, and non-experts harbor epistemic assumptions as well. Scientists, for example, have assumptions regarding who is in charge of knowledge production (Suldovsky et al. 2018) and disciplinary-specific conventions regarding how knowledge is produced and evaluated (O'Rourke and Crowley 2013); nonscientists similarly hold assumptions about who counts as an expert or scientist (Suldovsky et al. 2019). Epistemic beliefs about science and knowledge have been shown to be related to a multitude of other factors, including the efficacy of cross-disciplinary communication (Eigenbrode et al. 2007); students' learning, self-concept, motivation, and science achievement (Kampa et al. 2016); learning orientations toward science (Peer and Lourdusamy 2005); engagement preferences between scientists and stakeholder groups (Suldovsky et al. 2017); supernatural beliefs (Shtulman 2013); and socioeconomic status and achievement (Conley et al. 2004). Personal epistemology is typically regarded as complex and socially constructed, such that "the development of general epistemic beliefs begins at birth and continues to develop until the end of life" (Muis, Bendixen, & Haerle, 2006, p.31).

There are a multitude of ways to conceptualize and quantify epistemic beliefs, and there are various models that have been used in prior work (e.g., the reflective judgment model (King and Kitchener 2004)). The approach utilized in the current study is the concept of *personal epistemology*, which is defined as "an individual's cognitions about the nature of knowledge and the nature of knowing" (Pintrich 2002, p.390). Personal epistemology has been shown to be both domain-specific and domain-general[2]. That is, some personal epistemologies appear to be particularly tied to the scientific topic at hand, while others span various scientific topics (Muis et al. 2006). There is evidence that college students' epistemic beliefs vary, for example, between psychology and science more generally (Hofer 2000). Because the current study deals with a singular scientific domain—climate change—we treat epistemic beliefs about climate change as domain-specific.

There are three dimensions of personal epistemology that tend to be consistent across studies and have some cross-cultural validation (Peer and Lourdusamy 2005) of interest here, including certainty, simplicity (or "complexity"), and source (Pintrich 2002). *Certainty* refers to the degree to which a knowledge claim is judged as objectively concrete and true (more certain) or subjective and subject to change in the future (less certain). For example, one might view the existence of climate change as something that is objectively known and unlikely to change, or one might view climate change as something that is subject to refutation in the future. *Complexity* refers to the level of relativity within a given epistemic claim, including whether the thing to be known is simple and universally true across contexts (less complex) or whether it is convoluted and context-dependent (more complex). One might, for example, see climate change as objectively true (i.e., certain) but contingent on context (i.e., more complex), or they might see climate change as objectively true (i.e., certain) in a context-independent, universal sense (i.e., less complex). Finally, *source* refers to who can and should be relied upon to provide knowledge within a given domain, particularly the difference between reliance on external authorities and reliance on one's own direct experience. For someone who got the flu

[2] For an in-depth review and discussion of domain specificity and domain generality, see Muis, Bendixen, and Haerle (2006).

right after getting the flu shot, for example, they may defer to their own experience when judging the epistemic claim "you cannot get the flu from the flu shot," or they may defer to their doctor's advice and assume they must have gotten sick some other way, thus relying on an external (expert) source to decide whether or not to accept the epistemic claim.

While personal epistemology has been used to understand beliefs about science, it has rarely, if ever, been utilized to better understand engagement preferences within the context of controversial science. The primary goal of this study is to examine the relationship between epistemic beliefs and engagement preferences surrounding a controversial science topic: climate change.

2 Research questions

It has been repeatedly demonstrated that climate change beliefs (Dunlap et al. 2016) and communication preferences (Smith et al. 2016; Yeo et al. 2015) in the United States vary across political ideologies. As such, we anticipate that climate change engagement preferences will vary for liberals, moderates, and conservatives. What's more, because prior work shows that epistemic beliefs differ between political ideologies (Jost et al. 2013), we also expect the personal epistemologies of liberals, moderates, and conservatives to differ. Because public engagement preferences and epistemic beliefs surrounding climate change among lay publics have yet to be sufficiently assessed, we offer the following as research questions:

> RQ1: How do liberals, moderates, and conservatives compare regarding their engagement preferences surrounding climate change?
> RQ2: How do liberals, moderates, and conservatives compare regarding their epistemic beliefs about climate change?

Additionally, because the exact relationship between personal epistemology and engagement preferences remains underexplored, we offer the following as a research question:

> RQ3: What is the relationship between epistemic beliefs and engagement preferences surrounding climate change?

3 Methods

An online survey of Oregon residents was conducted of using a Qualtrics survey panel. Survey data were collected over the course of 3 weeks during March and April of 2019. Participants were compensated up to $5 for their participation.

3.1 Participants

Participants were current residents of Oregon (n = 1049) between the ages of 18 and 86 (M=44, SD=15.864). Participants were mostly white and non-Hispanic and evenly split between men and women. For a complete list of demographic statistics, see Table 1. A sample size calculator was used assuming a confidence level of 95% and the population size of Oregon (4.191 million at the time of writing). The ideal sample for these parameters was determined to be 1067. Our sample is slightly below that ideal (n=1049). The sample very

Table 1 Sample demographics

	Descriptive Statistics			
	N	%	Mean	St. Dev.
Age	1,049	100	44	15.864
Biological Sex				
Male	518	49.4		
Female	524	50.0		
Intersex	6	0.6		
Race / Ethnicity				
White	921	87.8		
Non-Hispanic	837	79.8		
Black	31	3.0		
American Indian or Alaskan Native	53	5.1		
Asian	49	4.7		
Native Hawaiian or Pacific Islander	8	0.8		
Political Ideology				
Very Liberal	108	10.3		
Liberal	200	19.1		
Moderate	452	43.1		
Conservative	196	18.7		
Very Conservative	92	8.8		
Education (highest degree earned)				
Less than high school (1)	54	5.2	3.44	1.443
High school graduate (2)	246	23.5		
Some college (3)	338	32.3		
2-year degree (4)	123	11.7		
4-year degree (5)	184	17.6		
Master's degree (6)	83	7.9		
Doctorate or M.D. (7)	20	1.9		

closely mirrors the demographic breakdown of the state for sex, race, and education (United States Census 2019), and our sample is 4 years older than the state average. For political ideology, our sample somewhat mirrors the state (Gallup 2014); our sample has more moderates (43.1% compared to 34% in the state) and liberals (29.4% compared to 28% in the state) and fewer conservatives (27.5% compared to 34% in the state). Regarding political party, our sample closely mirrors the state (Oregon Secretary of State 2019) for registered Republicans (~25%) and Democrats (~35%) and independent, non-affiliated, or not a member of the Democratic or Republican parties (~40%). Given these characteristics, we are confident that this sample is representative of Oregonians as a whole.

3.2 Measures

3.2.1 Epistemic beliefs

Epistemic beliefs were measured utilizing a validated scale from prior research that quantifies epistemic certainty, simplicity, and source (Peter et al. 2016). The original scale was adapted to be domain-specific and refer specifically to climate change for the purpose of this study. Participants responded on a *strongly agree* to a *strongly disagree* 5-point Likert scale to a variety of epistemic statements. To measure epistemic certainty, participants responded to six

statements, including: *Truth does not change for climate change*; and *Climate change has already been proven, and will not be refuted in the future* ($\alpha = 0.730$). Items were coded such that a higher score indicates higher perceived certainty. To measure epistemic complexity[3], participants responded to seven statements, including: *With respect to climate change*, *climate scientists have the same opinion*; and *There are always different answers to questions about climate change and you can never distinguish reliably which one is better* (reverse coded) ($\alpha = 0.508$). Items were coded such that a higher score indicates higher perceived complexity. For epistemic source, participants responded to five statements, including: *To form an opinion about climate change, it is best to rely on one's own experience*; and *If something a climate scientist says about climate change contradicts my own experience, I should defer to what the scientists says* ($\alpha = 0.520$). Items for "source" were coded such that a lower score indicates more reliance on one's own experience and a higher score indicates more reliance on climate science experts. Items for every epistemic belief were averaged to create a single index to be used for subsequent analysis and labeled *certainty*, *complexity*, and *source*. For a complete list of survey items, see Supplementary material.

3.2.2 Engagement preferences

Because engagement preferences for climate change have rarely been quantified using the models of public engagement with science, we were unable to find an existing and validated scale. As such, we created these survey items for the purpose of this study; all statements were responded to using a *strongly disagree* to *strongly agree* 5-point Likert scale. To measure the deficit model, we had participants respond to three statements: *I prefer to get information about climate change that I can listen to or read through on my own time*, *I would be interested in getting more information about climate change from climate scientists*, and *I trust climate scientists to give me accurate information about climate change* ($\alpha = 0.652$). To measure preference for the dialogue model, we had participants respond to five statements, including: *I would like the opportunity to tell climate scientists what I think about climate change*; *If given the opportunity, I would be willing to have a one-on-one conversation with a climate scientist*; *Climate scientists would likely be interested to hear what I think about climate change*; *Climate scientists are willing to listen to me*; and *Climate scientists are willing to listen to people like me* ($\alpha = 0.796$). To measure participation model preference, participants responded to three statements: *I would like to be involved in decision-making about the research being conducted about climate change*; *I would like to be involved in decision-making about how my community uses research about climate change*; and *I would like to be involved in decision-making about how my community responds to climate change* ($\alpha = 0.827$). Finally, for lay expertise, participants responded to the following statements: *I have valuable insights that would help climate scientists better understand climate change*; *Climate*

[3] Survey items used to measure epistemic complexity are similar to climate change consensus beliefs. To assess covariance between these two variables and ensure our operationalization of complexity is distinct from consensus perceptions, we ran a correlation analysis between the complexity index and two measures of consensus that were used within the same survey effort. Consensus perceptions were measured by asking participants what percentage of climate scientists agree that climate change is happening, and what percentage agree that climate change is human caused. We found that the complexity index is significantly and negatively correlated with both measures of consensus ($r=-0.197$, $p<0.001$; $r=-0.228$, $p<0.001$, respectively), such that higher complexity beliefs were associated with lower consensus perceptions. However, the shared variance of these variables (indicated by r^2) demonstrates little covariance, indicating that complexity perceptions are distinct from consensus beliefs.

scientists would have a better understanding of climate change if they talked to people like me; and *I would like to be more involved in conducting research about climate change* ($\alpha = 0.789$). Items for every engagement model preference were averaged to create a single index to be used for subsequent analysis and labeled *deficit*, *dialogue*, *participation*, and *lay expertise*.

3.2.3 Political ideology

Participants indicated their political ideology using a 5-point Likert scale that included *very liberal*, *liberal*, *moderate*, *conservative*, and *very conservative*. Those who indicated they were "liberal" (n=200) or "very liberal" (n=108) were grouped together under the term "liberal" and those who indicated they were "conservative" (n=196) or "very conservative" (n=92) were grouped together under the term "conservative" within this analysis.

4 Results

Research question 1 asked: How do liberals, moderates, and conservatives compare regarding their engagement preferences surrounding climate change? To answer this question, we ran a multivariate regression[4] that predicts engagement preferences using political ideology as a predictor. We find that ideology is a significant predictor, such that people identified as liberal assign significantly higher scores to the deficit model preference (3.76±0.05) than those of moderates (3.31±0.04) and conservatives (3.16±0.05). Furthermore, liberals assign significantly lower scores to the lay expertise model preference (2.2±0.06) than the other two groups (2.43±0.05 moderates and 2.41±0.06 conservatives). See Figures 1 and 2 for a visual representation of these results.

Research question 2 asked: How do liberals, moderates, and conservatives compare regarding their epistemic beliefs about climate change? To answer this question, we ran a multivariate regression that predicts epistemic beliefs using political ideology. We find that political ideology is strongly predictive of the different epistemic belief scores. In particular, we observe that conservatives are comparatively averse to epistemic certainty (2.69±0.05) when compared to moderates (2.93±0.04) and liberals (3.58±0.04). Both conservatives and moderates score complexity the highest (3.25±0.03 and 3.13±0.03, respectively), whereas liberals score it the lowest (2.8±0.03). In sum, we find that conservatives view climate science as less certain and more complex than moderates or liberals and are more likely to rely on their own experience in order to inform their understanding of climate change. The relationship between political ideology and the source score is similar to that of the certainty score although the differences between liberals and conservatives is less pronounced (liberal 3.41+/−0.04, moderate 3.03 +/−0.03 and conservative 2.89 +/− 0.04).

See Figure 3 for a summary of results.

Research question 3 asked: What is the relationship between epistemic beliefs and engagement preferences surrounding climate change? To identify the association between engagement preferences and epistemic beliefs, we ran a multivariate regression[5] predicting

[4] The models used capture response location dependence with location-specific random effects using the zip code of the latest address of residence from each respondent. We model the responses using multivariate linear models. In order to assess the uncertainty in the parameter estimates resulting from the model, we take a Bayesian approach and models were fitted using the *rstan* package in R.

[5] This model accounts for location and within-subject dependence.

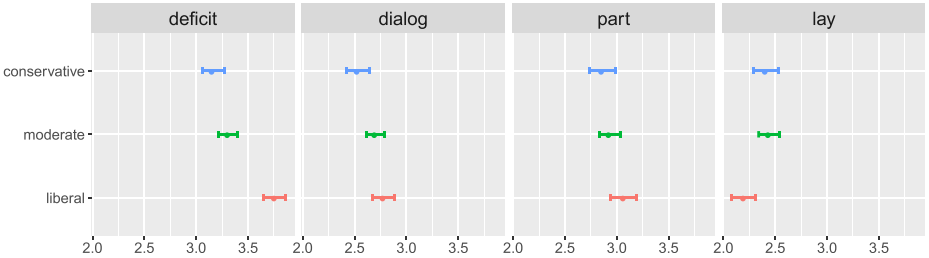

Figure 1 Political ideology vs engagement preference scores: 95% credible interval for the mean effects of the political ideology on the engagement preference scores

engagement preference using epistemic belief scores as predictors. From this model, we find that the strength and direction of the association between the dimensions of epistemic beliefs and engagement preferences for climate change varies (see Figure 4). For the deficit model, epistemic source (0.26±0.04) and certainty (0.36±0.04) are significant predictors, such that the more a person epistemically relies on experts over themselves and the more certain they view climate science, the more likely they are to prefer deficit-style engagement. Furthermore, complexity (0.01±0.05) was not a significant predictor for the deficit model. For dialogue, complexity (−0.12±0.06) and certainty (0.14±0.04) are significant predictors moving in opposite directions. The more certain a person's view is of climate science, the more likely they are to prefer dialogic communication. In contrast, the more complex the perception of climate science a person has, the less likely they are to prefer the dialogue model. Source was not a significant predictor for dialogue. For the participation model, source (0.10±0.05) and certainty (0.17±0.05) are positive and significant predictors, such that the more one epistemically relies on experts over themselves, and the more certain they view climate science, the more likely they are to prefer participation-style engagement. Finally, for lay expertise, source (−0.23±0.05) and certainty (−0.10±0.05) are negative and significant predictors, such that the

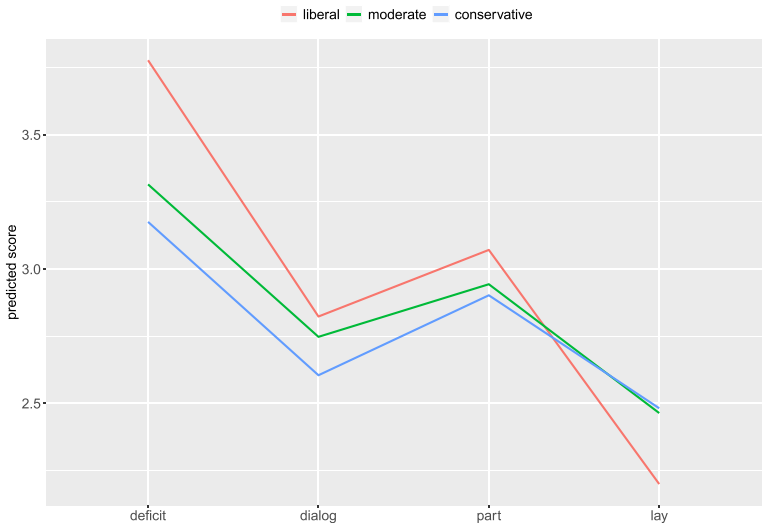

Figure 2 Posterior median values for the predicted engagement preference scores by political ideology. To obtain these curves, we set the epistemic belief scores at the empirical median values for the corresponding political ideology group

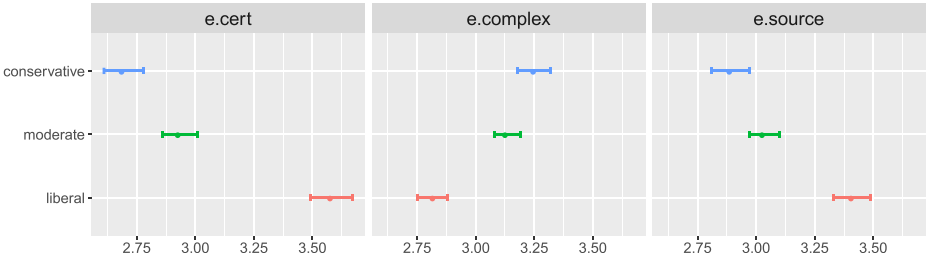

Figure 3 Posterior distributions of the mean effect of political ideology over epistemic belief scores

less a person epistemically relies on experts over themselves, and the less certain they view climate science, the more likely they are to prefer lay expertise-style engagement.

5 Discussion

This study sought to examine the relationship between epistemic beliefs and engagement preferences surrounding climate science in Oregon. Overall, we find support for the utility of epistemic beliefs as an avenue for developing a more sophisticated understanding of models of public engagement with science, particularly for understanding engagement model preferences. We find that liberals tend toward the deficit model of engagement more than moderates or conservatives and are significantly more likely than moderates or conservatives to view climate science as more certain and less complex, while relying on expert knowledge more than their own personal experience. By contrast, we find that conservatives are significantly more inclined toward lay expertise models of engagement than liberals and tend to view climate science as far less certain and more complex than both liberals and moderates. We also find that conservatives are significantly more likely to rely on their own personal experience over the knowledge of experts.

Regarding the relationship between epistemic beliefs and engagement preferences, we find unique patterns for each model of public engagement. For the deficit model, we find that the more one relies on expert knowledge over their own experience and the more certain one views climate science, the more likely they are to tend toward the deficit model. For the dialogue model, we find that the more certain and simpler one views climate science, the more likely they are to prefer the dialogue model. For the participation model, the more one relies on expert knowledge over their own experience, and the simpler and more certain they view climate science, the more likely they are to prefer participation-style engagement where they

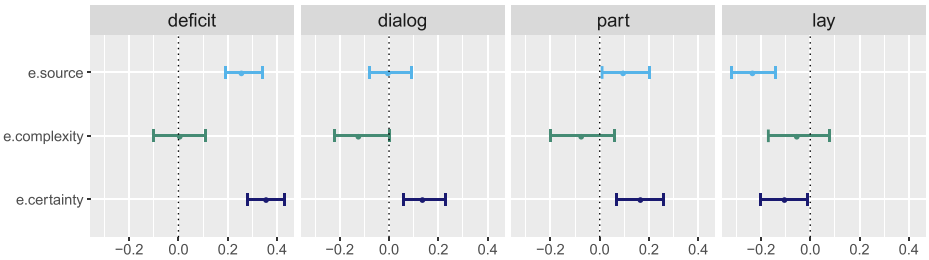

Figure 4 Engagement preference vs epistemic belief: 95% credible interval for the regression slopes of the epistemic belief scores on the engagement preference scores

are able to contribute to the directions and uses of science within their own communities. Finally, for the lay expertise model, we find that those who view climate science as less certain and rely on their own lived experience over the knowledge of experts are more likely to prefer a lay expertise model of engagement. For a visual depiction of study results for each ideological group (liberal, moderate, and conservative), see Figure 5.

For the deficit, dialogue, and participation models, it appears that complexity and certainty are held to greater or lesser extents in tension with one another, such that higher perceived certainty is associated with lower perceived complexity when predicting the three models. Interestingly, while complexity was not a significant predictor of a lay expertise model preference, the tension between certainty and complexity seems to diminish when predicting the lay expertise model (see Figure 4). This might be due to the nature of these epistemic beliefs and the realities of lay expertise engagement as it is operationalized here. To measure lay expertise, for example, we asked participants to respond to items that reflect their ability to aid climate scientists in understanding climate change. Assuming these items reflect participants' beliefs regarding the need for climate scientists to develop a better understanding climate change (e.g., "I have valuable insights that would *help climate scientists better understand climate change*," and "climate scientists would have a *better understanding of climate change* if they talked to people like me," emphasis added) and their own ability to contribute to that understanding, it follows that it would be associated with lower (rather than higher) perceived certainty and lower perceived complexity surrounding climate science.

5.1 Implications

This work adds to current literature in science communication in several ways. First, it supports the utility of attending to personal epistemology within science communication and public engagement. Specifically, we show that the personal epistemology for climate science varies for liberals, moderates, and conservatives living in Oregon. This is an important addition to our understanding of public understanding of climate change, as it suggests that we can go beyond assessing whether or not a particular public aligns with climate scientists about the facts (i.e., whether or not they believe climate change is real and human caused), and we can better understand and address the assumptions those publics make about climate science as a domain of knowledge. Given that epistemic beliefs are socially constructed (Jost et al. 2009) and that they change over time (Conley et al. 2004; Muis et al. 2006), attending to personal epistemology dynamics will also allow for the examination of the efficacy of engaging

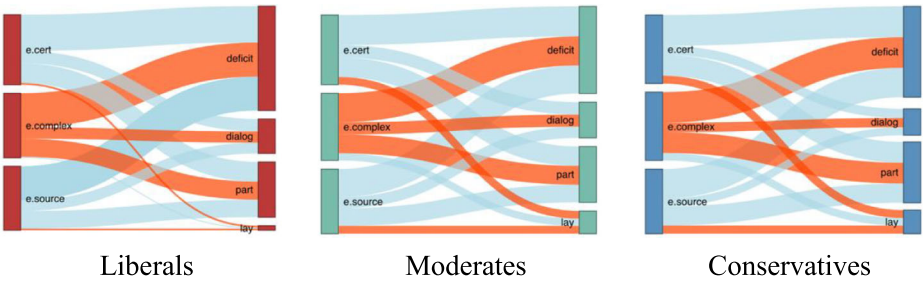

Figure 5 Estimated effect of the epistemic belief scores over engagement preferences by political ideology: liberal (left), moderate (center), and conservative (right). Blue and orange lines represent positive and negative slopes for the epistemic belief, respectively. Width of the connecting lines represents magnitude of effect

epistemic beliefs within communication efforts. It may be possible to cater to or alter personal epistemic assumptions about climate science to more effectively engage publics about climate change. For example, engaging with conservatives about climate change in a way that aligns with their epistemic source beliefs (i.e., appeals to their own direct experience) may be more effective than communication efforts that do not align (i.e., providing information from expert sources). Of course, a cross-sectional study of this nature cannot establish a causal relationship between epistemic beliefs and other variables. However, the current study does provide evidence that epistemic beliefs about climate change vary in meaningful ways among polarized groups, which suggests that these beliefs may serve as important leverage points for future public engagement efforts and communication interventions.

Second, these results suggest that there are underlying beliefs about the nature of knowledge that differ among ideological groups and could influence public perception of controversial science like climate change. Future work should explore the extent to which these beliefs function as a basis for other beliefs and whether these epistemic assumptions function as a perceptual filter through which climate change communication is filtered. This avenue of research may be of particular interest for scholars examining the motivated reasoning hypothesis, where people tend to reject information that is inconsistent with their previously held beliefs (e.g., Bolsen et al. 2014; Druckman and McGrath 2019; Kahan 2012). This current study suggests that one's personal epistemology may function as a part of those previously held beliefs. It is possible, for example, that in addition to avoiding facts that are at odds with our currently held beliefs, we also resist knowledge claims about climate science that do not align with our epistemic assumptions about certainty, complexity, and source. Of course, additional research is necessary to more clearly illuminate these dynamics and to assess the extent to which epistemic beliefs are subject to the motivated reasoning hypothesis.

Echoing the current study's emphasis on identifying underlying beliefs that influence public understanding of and engagement with climate science, one factor relevant for this effort that was not explored in the current study is the cultural authority of science. Prior work demonstrates, for example, that public perception of science is complex and is informed by several factors beyond generalized attitudes, including cultural representations of science and scientists (e.g., Gauchat 2011). Beliefs about the cultural authority of science and the role science ought to play in public policy issues also relate to declining trust in science among particular political groups (Gauchat 2012), making it particularly relevant for the exploration of models of public engagement with politically polarized science. Future work examining beliefs relevant for public engagement with science that extend beyond public understanding of scientific information ought to attend to these concepts as well.

Third, the current study offers additional insight into why the deficit model of engagement may be effective from some audiences (e.g., liberals) and ineffective, or even detrimental, for others (e.g., conservatives) when it comes to climate science. For example, we find that those who have a higher preference for the deficit model for climate change also tend to see climate science as being relatively certain and tend to see experts as an ideal source for climate change knowledge. It might be the case that when deficit model tactics are utilized for those who do not hold deficit-consistent epistemic beliefs (e.g., high certainty and the privileging of expert sources), it conflicts with their personal epistemology and, thus, is ineffective. For example, if one sees climate science as uncertain and they tend to rely on their own lived experience over the opinion of experts, it arguably follows that direct communication from climate science experts regarding the certainty of climate change would do little to change their minds. We recommend the future work to examine the relationship between epistemic beliefs and

engagement preferences for other scientific topics (e.g., genetically modified organisms) and with other populations to more clearly elucidate this relationship.

Of course, interacting with scientific experts via the deficit or other models of engagement is by no means the only way individuals interact with climate science. Additional information sources for climate science include partisan elites (Tesler 2018), competing communication from interest groups (Supran and Oreskes 2017), and partisan media (Levendusky 2013a, 2013b), all of which have been shown to play a role in public understanding of climate change. These competing communication sources, some of which aim to undermine scientific credibility and consensus (Oreskes and Conway 2011), serve to complicate the models of public engagement with science we outline here. Given the increasingly competitive information environment and the rise of fake news and misinformation (Lazer et al. 2018; Motta et al. 2020), future work ought to examine the connection between epistemic beliefs and engagement with a myriad of climate change information sources to build on the results reported here.

Finally, the current study has implications for science communication practitioners, as understanding the epistemic beliefs of lay publics may aid in the designing of more effective public engagement strategies. That is, for those who wish to engage publics utilizing any of the aforementioned models of engagement, it may prove useful to know how certain and complex they believe scientific knowledge to be, and the extent to which they rely on experts to give them knowledge about that scientific topic versus relying on their own experiences. If, for example, one is planning an engagement strategy for those who are more likely to rely on their own direct experience over the knowledge of experts, they can then incorporate those beliefs into their engagement strategy (e.g., avoid heavy reliance on expert knowledge and emphasize lived experience).

5.2 Limitations

This work has several key limitations to note. This study, while illuminating interesting relationships between epistemic beliefs and engagement preferences, is not able to explicate the effect of these beliefs on other variables of interest (e.g., support for climate mitigation policy, messaging effects, etc.). Future work ought to explore these dynamics to get a fuller picture of the role of personal epistemology in communication processes and outcomes. Additionally, this research was conducted within the state of Oregon and may not be representative of liberals, moderates, and conservatives within the broader United States. Future work should examine these variables within national and international contexts to better speak to the generalizability of these findings. Our measure of political ideology was a single self-report survey item.

To assess political beliefs, we used political ideology as defined by three groups: liberal, moderate, or conservative. These categories, while widely utilized in other work, may be a gross oversimplification of political beliefs and positions (Kalmoe 2020). Further, we did not account for political party membership within the current study. While the relationship between ideology and partisan identity is strong and increasing (Abramowitz and Saunders 2006), party membership has been shown to be an important factor for public perception of climate science (Merkley and Stecula 2018, 2020). Future work should examine the epistemic variables used here alongside more multidimensional measures of political beliefs and identities (e.g., the approach used by Pew Research Center 2017) and include a measure of party membership. Additionally, political ideology has been shown to exist along identity-based and issue-based dimensions, and identity-based ideological identities have been shown to drive

political polarization, even in the absence of issue-based ideological beliefs (Mason 2018). While we did not attend to the distinction between these two elements of political ideology in the current study, future work ought to examine the extent to which these two variants of ideological identities relate to epistemic beliefs. It is possible, for example, that epistemic beliefs for those with a strong identity-based political ideology significantly differ from those with an issue-based ideology. If such differences exist, these dynamics will carry important implications for science communication research and practice.

Two of the variables used in our analyses had somewhat low internal reliability, including the pre-existing items we adapted to measure epistemic complexity ($\alpha = 0.508$) and source ($\alpha = 0.520$). While it is not possible for us to know with our current data, the low reliability on these two items may have impacted the veracity of the results reported in this study. Future work should develop and use scales for these concepts with higher internal reliability and attempt to replicate the patterns reported here. Finally, this study was a cross-sectional survey and is unable to establish causal relationships between key variables. As such, future work should explore whether epistemic beliefs about climate science function as a cause or an effect for other beliefs.

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Availability of data and materials

Data are not available.

Declarations

Ethics approval This study was reviewed and approved by the Portland State University Institutional Review Board (Office of Research Integrity), Reference no. 196349-18.

Consent to participate Participants were provided with an informed consent form prior to participation in this survey that was reviewed and approved by the Portland State University Institutional Review Board.

Consent for publication All authors read and approved the final manuscript and consent to publication.

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