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Building Consensus for Ambitious Climate Action Through the *World Climate* Simulation

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Key Points:

- Climate change simulations that combine interactive role-play and computer models enable people to learn for themselves
- The widely used *World Climate* simulation reduces polarization and motivates climate action across political divides
- We also find evidence of a shift in *World Climate* participants' sociopolitical values from individualistic-hierarchical towards the center

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract Sociopolitical values are an important driver of climate change beliefs, attitudes, and policy preferences. People with "individualist-hierarchical" values favor individual freedom, competition, and clearly defined social hierarchies, while "communitarian-egalitarians" value interdependence and equality across gender, age, heritage, and ethnicity. In the US, individualist-hierarchs generally perceive less risk from climate change and express lower support for actions to mitigate it than communitarian-egalitarians. Exposure to scientific information does little to change these views. Here, we ask if a widely used experiential simulation, *World Climate,* can help overcome these barriers. *World Climate* combines an engaging role-play with an interactive computer model of the climate system. We examine pre- and post-*World Climate* survey responses from 2,080 participants in the US and use a general linear mixed model approach to analyze interactions among participants' sociopolitical values and gains in climate change knowledge, affect, and intent to take action. As expected, prior to the simulation, participants holding individualist-hierarchical values had lower levels of climate change knowledge, felt less urgency, and expressed lower intent to act than those holding communitarian-egalitarian values. However, individualist-hierarchs made significantly larger gains across all constructs, particularly urgency, than communitarian-egalitarians. Participants' sociopolitical values also shifted: those with individualistic-hierarchical values before the simulation showed a substantial, statistically significant shift toward a communitarian-egalitarian worldview. Simulation-based experiences like *World Climate* may help reduce polarization and build consensus towards science-based climate action.

Plain Language Summary The politicization of climate change makes it difficult to build support for urgently needed climate action. Americans who value individualism and traditional social hierarchies tend to be less concerned about climate change and less supportive of climate action than those who value interdependence and egalitarianism. While mass communication about climate change is more prevalent than ever, it may only make polarization worse. We ask whether a simulation-based approach can overcome the climate change communication challenges caused by polarization. In the widely used *World Climate* simulation, participants work together to create a global agreement to address climate change. They interact with each other and with a computer model, C-ROADS, which gives them immediate feedback about the long-term climate impacts of their decisions. We measure more than 2,000 participants' climate change knowledge, sense of urgency, and intent to act before and after the simulation and find that they make gains in all three areas. Participants who value individualism and social hierarchies make greater gains in their climate change beliefs and attitudes than others. Their social and political values also shift towards the center. Simulations like *World Climate* may be a promising way to reduce polarization and build support for climate action.

1. Introduction

Pledges and policies to address climate change are accelerating. Many nations, including the largest emitter, China, have now pledged to achieve carbon neutrality (Normile, 2020). More than 600 local governments in the US have developed climate action plans since 1991 (Markholf et al., 2020). The US federal government rejoined the Paris climate accord with stronger mitigation targets and there is widespread support for a "green recovery" from the recession induced by COVID-19 (Belesova et al., 2020). But these actions still fall far short of what is needed to meet international climate goals (Höhne et al., 2020), which require cutting greenhouse gas emissions to net zero by mid-century (IPCC, 2018). Climate action commensurate with the problem demands collective effort at

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an unprecedented scale, with people, organizations, and governments with diverse–and often divergent–interests taking action aligned with scientific understanding.

Despite the urgent need for science-based action, public beliefs and attitudes about climate change remain poorly aligned with science. While 58% of Americans believe climate change is mostly human-caused (Leiserowitz et al., 2021), only 35% of Republicans agree (Mildenberger et al., 2017). Worse, climate change beliefs often reinforce social identities, and vice versa, with stronger beliefs leading to stronger identification as a climate change "believer" or "skeptic," further entrenching initial positions (Bliuc et al., 2015; Kahan & Corbin, 2016). Attempts to change beliefs that are influenced by social forces are often perceived as a threat to personal identity and, therefore, actively rejected (Bliuc et al., 2015; Kahan & Corbin, 2016). At a broader scale, these trends are evident in the increasing politicization and polarization of climate change (Driscoll, 2019; Dryzek et al., 2019; McCright & Dunlap, 2011; McCright et al., 2013; Smith & Mayer, 2019) and other divisive issues in the US (Goldsworthy & Huppert, 2020; Schwirplies, 2018).

Here, we ask whether a widely used and engaging simulation, *World Climate,* can help build consensus for science-based climate action across the ideological spectrum. *World Climate* combines role-play with an interactive computer model of the climate system. We use a pre-/post-survey design to measure changes in sociopolitical worldview and climate change knowledge, affect, and intent to act in a sample of 2,080 Americans who participated in *World Climate*. We assess gains in climate change knowledge and attitudes among participants and how those gains interact with participants' sociopolitical values. We find that participants across the ideological spectrum make significant and substantive gains in knowledge, sense of urgency, and intent to act on climate and that participants who held more conservative, or individualistic-hierarchical, values made also shifted their sociopolitical values towards communitarian-egalitarianism.

Political orientation is now a stronger predictor of climate change beliefs than education, subjective knowledge, and direct experience of extreme events (Hamilton et al., 2015; Hornsey et al., 2016; Marquart-Pyatt et al., 2014; McCright & Dunlap, 2011; Smith & Mayer, 2019). People tend to fit their perception of climate change risks to match the beliefs of others who share their sociopolitical values, a phenomenon Kahan et al. (2010, 2012) refer to as the "cultural cognition thesis." Among those who hold more individualistic-hierarchical or conservative sociopolitical views, educational attainment, scientific literacy, and numeracy are inversely associated with belief in climate change (Kahan et al., 2012; Smith & Mayer, 2019). Mass communication and social media may only make polarization of climate change worse (Dryzek et al., 2019). User-tailored newsfeeds and social media expose individuals to views that generally agree with and reinforce their own initial position (Dryzek et al., 2019; Goldsworthy & Huppert, 2020; Sude et al., 2021). Social media may further exacerbate polarization through messenger bias, as individuals give more weight to information shared by members of their social group (Goldsworthy & Huppert, 2020; Menon & Blount, 2003).

While face-to-face, facilitated deliberation can reduce polarization and foster effective group problem-solving (Dryzek et al., 2019), most people do not have the opportunity or time to participate in real-world deliberations about climate change. Only 36% of American adults talk about climate change even occasionally (Marlon et al., 2018), even though a majority are worried about it. Most people underestimate the number of people who believe in and are concerned about climate change (Leviston et al., 2013; Van Boven et al., 2018). This misperception is particularly prevalent when applied to political conservatives, with both Democrats and Republicans strongly underestimating climate change beliefs among Republicans (Van Boven et al., 2018). These misperceptions foster pluralistic ignorance, or the tendency people have to avoid sharing their views because they falsely believe that others do not agree with them (Geiger & Swim, 2016).

New approaches to climate change communication, education, and decision support are clearly needed to overcome these barriers and motivate science-based action. Climate change communication efforts focused on information delivery have little impact, especially if beliefs are motivated by social and affective forces (Pearce et al., 2015). Instead, climate change communication efforts should work with, not against, social and affective forces. Recent research indicates that serious games and role-play simulations offer powerful communication approaches that engage social learning pathways (e.g., Flood et al., 2018; Rumore et al., 2016). An example is the *World Climate* simulation, which combines role-play that simulates climate policy negotiations and an interactive computer model, C-ROADS, that simulates the climate system's response to those policies (Rooney-Varga et al., 2018; Sterman et al., 2014). Participants take on the roles of delegates to the United Nations

climate negotiations and are asked to make emissions and land use decisions that, collectively, meet international climate goals of limiting warming to less than 2 °C above preindustrial levels. Their decisions are tested in the C-ROADS model, enabling them to learn for themselves about the expected climate response. Participants in *World Climate* show gains in their knowledge of climate change, sense of urgency about the problem, and desire to learn and do more about climate change (Rooney-Varga et al., 2018). The simulation incorporates key components of real-world "deliberative democracy," including facilitated deliberation, an objective that participants share, and access to credible, expert information, which together are thought to mitigate polarization and promote effective problem-solving (Dryzek et al., 2019). However, prior research has not determined if and how this simulation-based approach can overcome sociopolitical barriers to climate change communication. Here, we analyze the impact of *World Climate* on participants who hold sociopolitical values associated with dismissal of human-caused climate change. We also ask if and how participants' sociopolitical values shift in response to the simulation.

1.1. Hypothesized Interactions Between Sociopolitical Values, Climate Change Beliefs and Attitudes, and the *World Climate* Simulation

We hypothesize that participants who hold diverse sociopolitical values make gains in their knowledge of climate change science, their sense that urgent action is needed ("*Urgency*"), their belief that it is still possible to make a difference ("*Hope*"), and their intent to take action in the real world ("*Intent*"). We further hypothesize that participants who hold individualistic-hierarchical values make gains that are at least as large as their communitarian-egalitarian counterparts. Lastly, we hypothesize that participants' sociopolitical values shift during the simulation, as the need for urgent collective action across all delegations becomes evident and participants realize the interdependence of their decisions and the effect of those decisions on climate outcomes.

2. Materials and Methods

2.1. Sample and Data Collection

Our sample consist of 41 *World Climate* simulation sessions conducted between September 2015 and February 2020 in the US, with a total of 2,080 participants (Tables 1–2). These sessions represent diverse educational settings in which *World Climate* is used, including informal and formal education for high school, undergraduate, and graduate students, as well as sessions for educators and other professionals. Participants ranged in age from mid-teens (14–17 years old) to older adults (51–75 years old). They had diverse educational backgrounds and interest in climate change, from no prior education or interest to students or professionals who focus on climate change.

World Climate simulation sessions were conducted as described by Rooney-Varga et al. (2018), with all sessions between 1.5 and 3 h and held in-person. Facilitators included members of our research team, educators we trained, and educators who learned how to facilitate *World Climate* using our freely available online resources (https://www.climateinteractive.org/ and https://climatechangeinitiative.org/). The simulation is described in detail by Sterman et al. (2014). Briefly, participants take the roles of delegates to the United Nations climate negotiations and are tasked with creating an international agreement that limits global warming to 2 °C above preindustrial levels by 2,100. They are responsible for decisions to reduce greenhouse gas emissions, stop deforestation, and support afforestation within their own region or bloc. The role-play includes delegations representing the US, the European Union, other developed countries (Australia, Canada, Japan, and others), China, India, and other developing countries (most South American, African, and Middle Eastern nations). Participants' decisions are entered into the C-ROADS computer model (Sterman et al., 2012), which provides immediate feedback on expected global climate outcomes, including global temperature rise, ocean acidification, and sea level rise. The facilitator encourages participants to continue their negotiations until the international climate goal is met, assuming time allows.

2.2. Survey Instruments and Data Processing

We used a pre-/post-survey design to assess the impact of *World Climate* on participants' beliefs and attitudes about climate change and their sociopolitical values. Pre-surveys were administered shortly before each simulation.

Table 1
Overview of Session Information

Location	Setting	Self-selected[a]	Participants	Pre-surveys	Post-surveys	Matched	Usable cases[b]
Lowell, MA, USA	Undergraduate	Yes	39	100%	59%	54%	54%
Auburn, AL, USA	Undergraduate	No	55	98%	91%	89%	87%
Nashua, NH, USA	Undergraduate	Yes	38	100%	47%	29%	21%
Madison, WI, USA	Graduate	No	17	100%	100%	94%	82%
Butte, MT, USA	Undergraduate	No	50	78%	52%	40%	34%
Johnson City, TN, USA	Undergraduate	Yes	10	100%	80%	70%	70%
St Louis, MO, USA	Undergraduate	No	35	80%	49%	34%	34%
Durham, NH, USA	Undergraduate	Yes	20	100%	100%	100%	95%
Whittier, CA, USA	Undergraduate	Unknown	41	83%	68%	61%	54%
Lowell, MA, USA	Undergraduate	Yes	20	85%	30%	25%	25%
Presque Isle, ME, USA	High School	No	75	87%	77%	73%	65%
Greeneville, TN, USA	Undergraduate	No	108	100%	74%	69%	63%
Cambridge, MA, USA	Graduate	No	100	98%	62%	52%	49%
Charleston, WV, USA	Professional/Community	Yes	12	58%	67%	50%	50%
Portland, ME, USA	Professional/Community	Yes	12	100%	100%	92%	75%
Cambridge, MA, USA	Graduate	No	270	59%	34%	31%	30%
Birmingham, AL, USA	Undergraduate	No	25	92%	88%	88%	88%
Cambridge, MA, USA	Graduate	No	120	97%	81%	54%	54%
Cambridge, MA, USA	Graduate	No	60	80%	77%	70%	65%
Cambridge, MA, USA	Graduate	No	50	96%	94%	82%	80%
Cambridge, MA, USA	Undergraduate	Yes	9	100%	89%	78%	67%
Lowell, MA, USA	Undergraduate	No	25	80%	56%	56%	56%
Lowell, MA, USA	Undergraduate	No	19	53%	58%	53%	53%
Portland, OR, USA	Undergraduate	Yes	42	52%	45%	45%	40%
Lowell, MA, USA	Undergraduate	No	30	87%	70%	63%	60%
Miami, FL, USA	High School	No	40	100%	63%	40%	23%
Lowell, MA, USA	Undergraduate	Yes	40	75%	55%	50%	48%
Fayetteville, AR, USA	Undergraduate	Yes	27	85%	85%	85%	67%
Cambridge, MA, USA	Graduate	Yes	90	100%	86%	69%	67%
Cambridge, MA, USA	Graduate	No	35	100%	74%	66%	66%
Lowell, MA, USA	Undergrad	Yes	26	73%	69%	69%	65%
Auburn, AL, USA	Undergrad	Yes	15	100%	87%	80%	80%
Cambridge, MA, USA	Graduate	No	111	95%	63%	52%	52%
Cambridge, MA, USA	Graduate	No	110	99%	86%	64%	60%
Lowell, MA, USA	Professional/Community	Yes	24	100%	54%	42%	25%
Boston, MA, USA	High School	No	90	97%	93%	90%	83%
Auburn, ME, USA	Undergraduate	Yes	31	94%	94%	81%	65%
Athens, GA, USA	High School	No	70	100%	63%	56%	50%
Lawrence, KS, USA	High School	No	66	92%	100%	67%	56%
Miami, FL, USA	High School	No	30	93%	93%	83%	83%
Durham, NH, USA	Undergraduate	Yes	24	100%	96%	92%	88%

[a]Indicates whether or not participants chose to participate in a climate change-related activity or course (yes) or were required to participate as part of a program or course unrelated to climate change (no). [b]Usable cases, defined as the number of participants with no prior experience with *World Climate,* and who provided matched pre- and post-surveys and responded to all *Values* survey items.

Table 2
Demographic Characteristics of the Individuals Who Provided Usable Cases

Characteristic	N	% of total
Gender[a]		
Female	514	46%
Male	480	43%
Other	7	1%
Missing	107	10%
Age Range[a]		
14–17	256	23%
18–24	238	22%
25–35	302	27%
36–50	177	16%
51–75	28	3%
76+	0	0%
Missing	107	10%
Racial/Ethnic Identity		
African American/Black	100	9%
Asian	214	19%
Hispanic/Latinx	167	15%
Pacific Islander	2	< 1%
White	427	39%
Other	90	8%
Missing	108	10%
Parent/Guardian's Education		
No school	7	1%
Elementary only	31	3%
Secondary	275	25%
Some postsecondary	219	20%
Bachelor's degree or higher	573	52%
Missing		< 1%

[a]The survey asked participants to select an age range (e.g., 25–35) rather than entering their age (see Supporting Information S1 for full survey).

Post-surveys were administered within a few minutes to several days after the simulation. The period of time between the end of the simulation and the post-survey was kept as short as possible to minimize the potential impact of factors other than *World Climate*. Sessions were held on different dates, ruling out the possibility that any particular external climate-related event influenced pre-to post-survey shifts in participants' responses across sessions. The surveys are included in full in the supplementary materials and were approved by the institutional review board of the University of Massachusetts Lowell (Protocol 16-049-ROO-XPD). Survey items that addressed participants' sociodemographic traits and their climate change knowledge, affect, and intent to act were the same as in Rooney-Varga et al. (2018). Survey items that measured participants' sociopolitical values (taken from Kahan et al., 2012) were not included in prior research about the impact of *World Climate*. Consent was collected through both written and oral protocols. All participants were informed that the surveys were voluntary, that their responses would be kept confidential, and that their responses would have no impact on their educational status if *World Climate* was part of an academic program.

Pre- and post-survey items (Table 3; Text S1–S2 in Supporting Information S1) were designed to assess knowledge about climate change causes and impacts, affective response to climate change, and intent to learn and do more to address it (Rooney-Varga et al., 2018), as well as to assess participants' sociopolitical values (Kahan et al., 2012). Lastly, demographic questions include gender, age, race/ethnicity, highest educational level achieved by participants' parents/guardians, and self-assessed socioeconomic status. Participants were also asked to respond to open-ended questions about how the simulation affected their understanding of and feelings about climate change.

For each session, we calculated the percentage of participants within a session who provided usable data and recorded whether or not participants self-selected into a climate change-related activity. Respondents were included in the full analysis (i.e., provided "usable cases") if they participated in a session in the United States, reported no previous experience with *World Climate,* were of at least high school age, provided pre- and post-surveys that could be matched to each other, and had completed the *Values* questions on both surveys. Across the 2,080 participants in our sample, 87% responded to the pre-survey (range: 52%–100% per session), 70% responded to the post-survey (range: 32%–100%) and 55% of all participants met all of the criteria for including cases. This resulted in 1,108 usable cases. Note that we refer to cases that include all responses relevant to a particular construct or analysis as "valid cases." The datasets for this research are freely available (Rooney-Varga et al., 2021).

2.3. Constructs Analyzed: Beliefs and Attitudes About Climate Change and Sociopolitical Values

We analyzed two sets of constructs: one set assessed participants' beliefs, feelings, and intent to take action about climate change (Rooney-Varga et al., 2018), the other assessed participants' sociopolitical values (Kahan et al., 2007, 2012). Construct values were only calculated for respondents who answered all survey questions within a given a construct. Climate change-related constructs were identified by Rooney-Varga et al. (2018) using exploratory factor analysis. They include: "*Impacts*," which combines questions about participants' knowledge about the risks posed to natural and human systems by climate change; "*Urgency*," assessing participants' feelings of personal connection to and worry, guilt, fear, alarm, outrage, or anger about climate change; "*Hope*," assessing whether participants feel hopeful, empowered, or discouraged about climate change; and "*Intent*," which included

Table 3
Survey Items Associated With Climate Change-Related and Sociopolitical Values Constructs

Construct	Items
Impacts	• Impacts of climate change—Increased temperatures globally
	• Impacts of climate change—Increased incidence and intensity of heat waves
	• Impacts of climate change—Increased rates of extinction of plant and animal species
	• Impacts of climate change—Increased global sea level
	• Impacts of climate change—Increased intensity of storms across many regions
	• Impacts of climate change—an overall decrease in clean, potable water globally
Urgency	• How worried are you about climate change?
	• Feelings about climate change—Not Guilty to Guilty
	• Feelings about climate change—Calm to Outraged/Angry
	• Feelings about climate change—Unconcerned to Alarmed
	• Feelings about climate change—Not Afraid to Very Afraid
	• How important is the issue of climate change to you personally?
Hope	• Feelings about climate change—Hopeless to Hopeful
	• Feelings about climate change—Discouraged to Empowered
Intent	• Likelihood—Take action to reduce your personal carbon footprint
	• Likelihood—Discuss climate change with your family and friends
	• Likelihood—Discuss climate change with your peers
	• Likelihood—Take some form of political action in support of climate change policy
Values	• The government interferes far too much in our everyday lives
	• Sometimes government needs to make laws that keep people from hurting themselves
	• It's not the government's business to try to protect people from themselves
	• The government should stop telling people how to live their lives
	• The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals
	• Government should put limits on the choices individuals can make so they don't get in the way of what's good for society
	• We have gone too far in pushing equal rights in this country
	• Our society would be better off if the distribution of wealth was more equal
	• We need to dramatically reduce inequalities between the rich and the poor, whites and people of color, and men and women
	• Discrimination against minorities is still a very serious problem in our society
	• It seems like blacks, women, homosexuals, and other groups don't want equal rights, they want special rights just for them
	• Society as a whole has become too soft and feminine

survey items asking participants about the likelihood that they would act to reduce their personal carbon footprint, talk about climate change with others, or take political action.

We use Kahan et al., 2012 constructs to assess an individual's sociopolitical values, which combines two scales referred to as "group" and "grid" (Douglas & Wildavsky, 1982). The "group" dimension ranges from communitarian (valuing the role of the community in an individual's life), to individualistic (valuing individual freedoms and competition). The "grid" dimension measures the extent to which people value defined social hierarchies, with a scale ranging from egalitarian to hierarchical. In the combined scale, a "communitarian-egalitarian" is someone who values interdependence and equal status across gender, age, heritage, and ethnicity, while an "individualistic-hierarch" is someone who values individual freedoms, competition, and defined social hierarchies (Kahan et al., 2012). We use the term "sociopolitical values" ("*Values*") to describe the latent variable measured

by these scales, which include beliefs about the role of government, the distribution of wealth, and the rights of minorities and other vulnerable groups. The items from the surveys that corresponded to these constructs are shown in Table 3. All survey items used to define constructs were included on both the pre- and post-survey. Cronbach's alpha was used to confirm the reliability of each of the constructs in the current sample. All constructs showed sufficient reliability with Cronbach's $\alpha > 0.64$, with all but *Impacts* and *Hope* yielding Cronbach's $\alpha > 0.78$ (Table S1 in Supporting Information S1) (Cronbach, 1951; Taber, 2018).

We ensured a consistent scale with a minimum value of one indicating the most communitarian or egalitarian viewpoint and a maximum value of five indicating the most individualistic or hierarchical viewpoint. The responses to the twelve items were then averaged, with low values indicating a more communitarian-egalitarian value set and higher values a more individualistic-hierarchical one.

We used factor-based scores as a simple, intuitive approach to combine survey responses for all items that fell within a given construct (Comrey & Lee, 1992). Climate change-related survey questions had responses that ranged from binary responses to five-point Likert scales. To ensure equal weighting of all survey items, we recoded responses to a scale with a minimum value of zero and a maximum value of one. Construct scores were then calculated by taking the mean of the recoded response values for all survey items in a given construct. All sociopolitical value question responses were on a five-point Likert scale, so rescaling was not necessary.

2.4. Pre-to Post-Simulation Changes in Constructs

Two-tailed paired t-tests were used to test for statistically significant shifts in the values of constructs from pre-to post-simulation. Effect sizes were assessed by Cohen's *d* (Cohen, 1992), the difference in the post- and pre-survey means relative to the standard deviation in responses, using the pooled standard deviation for the pre- and post-surveys. Effect sizes of 0.3, 0.5, and 0.8 are generally considered small, medium, and large, respectively (Cohen, 1992).

2.4.1. Gains in Constructs Among Individualistic-Hierarchical and Communitarian-Egalitarian Participants

To assess whether participants' pre-simulation sociopolitical values affect how they reacted to the simulation, we divide the participants into two groups based on their *Values* scores on the pre-survey, using the median value (2.33 on the 5 point scale) as the cutoff between the two groups (Kahan et al., 2010). Individuals with a pre-simulation *Values* score of 2.33 or below were placed in the communitarian-egalitarian (CE) group ($N = 576$); those with higher scores were placed in the individualistic-hierarchical (IH) group ($N = 532$). Note that we grouped individuals with a *Values* score of 2.33 in the CE group because this score is closer to average CE than average IH scores. The CE group is therefore larger than the IH group. We then use independent sample t-tests and Cohen's *d* effect sizes to determine whether participants in each sociopolitical values group showed significant pre-to post-survey changes in climate change knowledge (the construct *Impacts*), affect (*Urgency* and *Hope*), intent to take action (*Intent),* and sociopolitical values (*Values)*. We also compare the communitarian-egalitarian to the individualistic-hierarchical participants to assess any differences in their pre-simulation levels and gains in climate change knowledge, affect, and intent.

2.5. Interactions Between Sociopolitical Values and Simulation Learning Outcomes

In addition to direct comparisons of construct means via t-tests, we use general linear mixed models (GLMMs) to assess the effects of sociopolitical values on changes in climate change knowledge, affect, and intent associated with the simulation. Mixed models include both fixed factors (i.e., predictors) and random factors, which account for the non-independence of participants' pre- and post-survey responses and any effect of session on outcomes. By accounting for random variation at the participant and session level, GLMM allows for results to be generalized to the population that the participants were drawn from (Fairbrother et al., 2019). Constructs describing climate change beliefs and attitudes were assessed pre- and post-simulation and are therefore non-independent repeated measures for each participant. Similarly, participants in a given session shared an experience that may have differed from other sessions, making them non-independent. Both participant and session are included as random factors in all models, with participant nested within session, providing a way to account for the non-independence of pre- and post-surveys from a given respondent as well as respondents who participated in a particular

session. GLMMs were run using SAS version 9.4 and the distributions of conditional residuals were examined to ensure that assumptions about their normality were not violated. Models for each outcome were compared using maximum likelihood estimates. Restricted maximum likelihood was used to estimate the final fixed effect coefficients, variance, and covariance parameters (Kenward & Roger, 1997).

Our primary interest is in the interaction between participants' sociopolitical values and the learning impact of the simulation, including pre-to post-simulation change in participants' values. We therefore divide participants into four groups based on their pre- and post-survey *Values* constructs: (a) those who held more communitarian-egalitarian values both before and after the simulation (CE_CE, with *Values* scores ≤2.33 on both pre- and post-surveys, $N = 488$); (b) those who held more individualistic-hierarchical values both before and after the simulation (IH_IH, with *Values* scores >2.33 on both pre- and post-surveys, $N = 423$); (c) those who shifted from the communitarian-egalitarian to the individualistic-hierarchical category from pre-to post-simulation (CE_IH, $N = 88$); and (d) those who shifted from more individualistic-hierarchical to more communitarian-egalitarian (IH_CE, $N = 109$). We use GLMM to analyze the effects of participants' sociopolitical values category, participation in the simulation (i.e., surveys collected pre- or post-simulation, referred to as "pre vs. post"), and the interaction between participation in the simulation and sociopolitical values category on each of the outcome constructs (*Impacts, Urgency, Hope*, and *Intent*).

To ensure that any statistically significant effects of the simulation (pre vs. post responses), sociopolitical values, or their interaction on outcome constructs were not explained by response bias, selection bias, or sociodemographic factors, we also run full models that include: (a) the percentage of participants in a given session who provided usable cases (to test for response bias); (b) whether or not a participant self-selected into a climate change or sustainability-related activity including *World Climate* (selection bias) versus participating as part of a required course; and (c) all sociodemographic factors we measured (Table 2). Our approach to address the potential for response and selection bias are explained in more detail below. Note that our sample was not randomly drawn from the general population and is therefore not expected to be representative of the American public. In addition, sessions with the youngest participants (high school students, Table 1) were drawn from programs serving low-income, first-generation-to-college students, making it likely that age correlates with other sociodemographic traits in our sample. We therefore do not expect sociodemographic effects that may be observed in our sample to be extensible to the broader American population. Our goal is not to determine whether sociodemographic factors affect the impact of *World Climate*, but rather if and how sociopolitical values do.

2.6. Assessing Threats to External Validity

We assess two sources of potential bias that could threaten the external validity of our findings. First, survey completion was optional, raising the possibility of response bias. Participants who elected to complete surveys may have held prior views about climate change that were more extreme than those who did not. They may have also had more extreme reactions to the simulation than those who did not complete surveys. Second, about 80% of the respondents in our sample were required to participate in *World Climate* as part of a course unrelated to climate change or sustainability and therefore should not introduce selection bias. However, the remaining ≈20% chose to participate in a climate change-related activity. These participants' responses may introduce bias if they were more motivated to learn about climate change or take climate action than a representative sample.

We test for response bias by (a) comparing pre-survey values of constructs for participants who completed both pre- and post-surveys to those who responded to the pre-survey alone; (b) comparing post-survey values of constructs for participants who completed both pre- and post-surveys to those who responded to the post-survey alone; and (c) testing whether the percent of matched cases from a given session had a significant effect in linear mixed models (as explained above). We test for selection bias by (a) testing the significance of an indicator variable that encoded whether or not participants self-selected into a climate change-related activity; and (b) comparing pre-survey and gains in constructs for participants who self-selected into a climate change activity to those who did not (as explained above). Independent sample t-tests were used to compare means.

3. Results

3.1. Examples of Open-Ended Responses

While a full qualitative analysis of open-ended responses is beyond the scope of this study, we provide examples in which participants share the impact of the simulation on their values or social identity. Participants described how the simulation offered an opportunity to deliberate with, and learn from, others who did not necessarily share their sociopolitical identity or perspective. For example.,

Talking and debating with other groups made me see different perspectives from others. Undergraduate participant, University of Massachusetts Lowell.

I liked the intentional mixing of people into country/industry groups with which they normally would not identify though--that was a good empathy tool. Graduate student participant, MIT.

Have learnt to be more empathetic and think from other countries (sic) perspective too as I was representing a different country than my native country. Graduate student participant, MIT.

Others referred to coming to the realization that collective action, instead of individualism, is fundamental to successfully addressing climate change:

Conflicted on the balance between promoting my own interests, the interests of those I represented, and the combined interests of all of us. Graduate student participant, MIT.

I was not aware that I was thinking about it with a zero-sum game mentality. This simulation was eye opening to the possibilities and economic benefits of addressing climate change. Graduate student participant, MIT.

Because I studied mechanical engineering, I had a biased view on climate change and supported (a) fossil fueled economy over (a) clean one and was of the opinion that developing countries have the right to use fossil fuel(s) to develop their economies. After this workshop I realized that climate change is not an individual problem anymore. It needs collective efforts of many countries to actively solve the wicked problem; Climate change. Graduate student participant, MIT.

Lastly, some participants described how the simulation offered an opportunity to practice advocacy and their intent to take action in the real world. For example.,

I did convert some non-believers in my cohort! I encourage (people to) reduce, recycle, reuse. Every bit helps. Graduate student participant, MIT.

I felt that I needed to study the (sic) climate change more. I am working for the world[s] third (largest) coal power generation plant construction company. Personally, I feel I should stop this business. Graduate student participant, MIT.

3.2. Comparison of Individualist-Hierarch and Communitarian-Egalitarians Climate Change Beliefs and Attitudes

As expected, sociopolitical values are a strong predictor of climate change knowledge, affect, and intent to act. Participants who began the simulation with more individualistic-hierarchical values show lower levels of knowledge about climate change impacts (*Impacts*), sense of urgency (*Urgency*), and intent to act (*Intent*), and higher levels of hope and empowerment (*Hope*) than those with more communitarian-egalitarian values, as is evident from comparison of pre-survey means (Table 4). Again, effect sizes given are Cohen's *d* (Section 2.4, Cohen, 1992). It should be noted on this and subsequent tables that the numbers of participants are not the same for each construct. This is because not all participants provided responses to all survey items within each construct and constructs were only calculated when all items had been completed. In particular, *Impacts* had fewer complete variables because participants were offered a "don't know" option that was not scored.

Across our entire sample population, we find statistically significant and substantial pre-to post-simulation gains in Impacts, Urgency, Hope, and Intent (Table 5). There was also a very small but statistically significant shift in towards communitarian-egalitarian values associated with participation (Table 5). Note that for many of these constructs, the total N values are lower than the pre-survey N values from Table 4 because not all participants who

Table 4
Comparison of Pre-Survey Means for Constructs of Participants Who Began the Simulation With More Communitarian-Egalitarian (CE) Values to Those With More Individualistic-Hierarchical (IH) Values

	CE			IH				
Variable	Mean	SD	N	Mean	SD	N	*p*-value	Effect size
Impacts	0.896	0.121	493	0.764	0.176	432	< 0.001	−0.885
Urgency	0.706	0.156	565	0.568	0.194	519	< 0.001	−0.788
Hope	0.461	0.204	571	0.515	0.185	526	< 0.001	0.277
Intent	0.767	0.183	570	0.610	0.212	528	< 0.001	−0.795

provided complete pre-survey responses for a given construct also provided complete responses for it on the post-survey.

We asked whether the simulation would have different impacts on participants who began the simulation with more CE values (*Values* score <2.33) as compared to those who began it with more IH values (*Values* score >2.33). Both groups show statistically significant gains in knowledge about climate change Impacts, as well as *Urgency, Hope*, and *Intent* to take action (Tables 6–7). For constructs *Impacts, Urgency*, and *Intent* to take action, the gains were higher for participants who began the simulation as more individualistic-hierarchical compared to those who were more communitarian-egalitarian (Tables 6–8).

Finally, pre-to post-simulation changes in *Values* suggest that the simulation had a depolarizing effect: participants who began the simulation with more individualistic-hierarchical values showed shift towards communitarian-egalitarian values ($p < 0.001$, Cohen's $d = -0.290$, Table 7). There is also a small increase in the mean *Values* score for those initially classified as having communitarian-egalitarian, but it is not statistically significant. Note that for GLMMs, participants were divided into four groups based on their sociopolitical *Values* score before and after the simulation and that similar numbers of participants fell into the CE_IH as IH_CE group (see below). However, as shown in Tables 5–7, when both numbers of participants and the extent of their pre-to post-shift in *Values* scores are taken into account, the overall shift is towards communitarian-egalitarian values, especially among those who begin the simulation with more individualistic-hierarchial values.

3.3. Interactions Between Sociopolitical Values and Climate Change Knowledge, Affect, and Intent

General linear mixed models (GLMMs) for climate change-related outcome variables show a statistically significant effect of sociopolitical group on pre- and post-simulation knowledge about climate impacts, sense of urgency and hope about climate change, and intent to take action, with individualistic-hierarchs showing lower levels of *Impacts*, *Urgency,* and *Intent,* but higher levels of *Hope* (Figure 1; Table 9). The base model is shown in Table 9, while the full model (which controls for sociodemographic traits) is shown in Table S5 in Supporting Information S1. Pre-to post-simulation effects are significant for all constructs (Tables 9, S5 in Supporting Information S1, see overall *p*-values for Pre vs. Post effects), indicating that participating in *World Climate* is associated with gains in climate change knowledge, affect, and intent, even among individualist-hierarchical participants. GLMMs also show that sociopolitical values affect climate change knowledge about *Impacts,* sense of *Urgency* and *Hope,* and *Intent* to act (Tables 9, S5 in Supporting Information S1, see overall *p*-values for sociopolitical values Group). The significant interaction between sociopolitical values and pre- versus post- for *Urgency* shows that participants who hold more conservative values (i.e., IH_IH group) actually make the greatest gains in *Urgency* (Table 9, Group * Pre vs. Post effect). Compared to participants who fall within the IH_IH group, gains in *Urgency* for those who hold communitarian-egalitarian values (i.e., CE_CE group) are statistically significantly lower as is evident from the model coefficient for the interaction between CE_CE values and pre versus post simulation (−0.020, $p = 0.050$).

Table 5
Comparison of Pre- and Post-Survey Means for Constructs for all Participants

		Pre		Post			
Variable	N	Mean	SD	Mean	SD	*p* value	Effect size
Impacts	860	0.837	0.160	0.886	0.157	< 0.001	0.309
Urgency	1,052	0.641	0.187	0.716	0.172	< 0.001	0.417
Hope	1,080	0.489	0.196	0.550	0.236	< 0.001	0.281
Intent	1,076	0.692	0.211	0.762	0.206	< 0.001	0.336
Values	1,108	2.343	0.594	2.296	0.625	< 0.001	−0.077

3.4. Threats to External Validity

To assess potential response bias in our voluntary surveys, we compared either pre- or post-survey construct values and sociodemographic factors for participants who provided only pre-survey or post-survey ("unmatched" survey) responses to those who provided both pre- and post-, or "matched" surveys (Tables S2–S3 in Supporting Information S1). With the exception of participant age, no construct values or sociodemographic factors show statistically significant, substantive differences between matched and unmatched surveys. Older participants were less likely to provide matched survey responses (effect sizes of 0.256 and 0.289, for pre- and post-surveys, respectively; $p < 0.001$ for both pre- and post-surveys; Table S2–S3 in Sup-

Table 6
Comparison of Pre- and Post-Survey Means for Constructs for Participants Who Began the Simulation With More Communitarian-Egalitarian Values

		Pre		Post			
Variable	N	Mean	SD	Mean	SD	*p* value	Effect size
Impacts	470	0.894	0.122	0.938	0.117	< 0.001	0.368
Urgency	545	0.707	0.153	0.769	0.138	< 0.001	0.426
Hope	560	0.464	0.204	0.519	0.241	< 0.001	0.246
Intent	557	0.766	0.183	0.826	0.172	< 0.001	0.338
Values	576	1.885	0.345	1.905	0.483	0.159	0.048

porting Information S1), perhaps because younger participants were in high school programs that administered surveys in-person, while most other programs sent survey links to participants before and after the simulation. There was also a significant effect of gender, with female participants being more likely to provide matched cases (Table S3.B in Supporting Information S1). We test for response bias by determining whether the fraction of participants who provide matched cases for a given session has a significant effect in GLMMs (Table S5 in Supporting Information S1). We find no effect of response level in the models tested.

A minority of our participants (~20%) self-selected into a climate change-related activity and could have introduced selection bias into our results. Comparison of gains for constructs for participants who self-selected into a climate change-related activity versus those who did not indicated no difference between the two groups with one exception: gains in *Urgency* were lower for participants who self-selected ($p < 0.001$, effect size = −0.230; Table S4 in Supporting Information S1). Note that t-tests and associated Cohen's *d* effect sizes only take one variable into account at a time. In contrast, GLMMs test for the significance of a particular effect (such as self-selection or response rate) when other effects are also taken into account. GLMM analysis of potential selection and response bias indicated no detectable effect in mixed models (Table S5 in Supporting Information S1), indicating that these potential biases do not pose a threat to external validity of our analyses.

4. Discussion

Our results show that *World Climate* is an effective way to motivate science-based climate action across audiences with diverse sociopolitical views. Before participating in *World Climate* participants holding more individualist-hierarchical values had lower levels of climate change knowledge, felt less urgency, and expressed less intent to take climate action than those with more communitarian-egalitarian values. But instead of remaining entrenched in their positions, participants with individualistic-hierarchical values made significant and substantive gains in climate change knowledge, affect, and intent to act. Their sense of urgency about climate change and their intent to do something about it grew more than participants with communitarian-egalitarian values. Interestingly, the simulation is also associated with a shift in sociopolitical values: participants who began the simulation with individualistic-hierarchical values show a statistically significant and substantive shift toward communitarian-egalitarianism. Taken together, these results indicate that *World Climate* builds support for science-based climate action, even among participants whose sociopolitical values predispose them to dismis it.

Several aspects of *World Climate* likely contribute to its effectiveness in overcoming social and psychological barriers to climate change communication. Research shows that real-world exercises in deliberative democracy reduce polarization and promote effective group problem-solving (Dryzek et al., 2019). The simulation incorporates key features of deliberative democracy: the roles bring the interests of stakeholders with diverse perspectives into an interactive context, it is externally facilitated by a neutral party, and it provides participants with objective expert information without telling them what their positions and actions should be (Dryzek et al., 2019). We find similar impacts on participants' beliefs and intent to act outside of the simulation. However, unlike real-world deliberations, the actions and decisions participants take in *World Climate* are simulated and, therefore, free of cost and risk. Participants take on a fictional role, often different from their real-world roles and beliefs, allowing them to see the problem from new perspectives. They are free to test new ideas and share views that they can ascribe to their fictional role.

Shifts from individualist-hierarchical to communitarian-egalitarian sociopolitical values associated with the simulation likely result from insights participants gain from the social dynamics of the role-play simulation. The simulation typically begins with participants playing out the consequences of

Table 7
Comparison of Pre- and Post-Survey Means for Constructs for Participants Who Began the Simulation With More Individualistic-Hierarchical Values

		Pre		Post			
Variable	N	Mean	SD	Mean	SD	*p* value	Effect size
Impacts	390	0.769	0.174	0.822	0.175	< 0.001	0.304
Urgency	507	0.569	0.194	0.658	0.186	< 0.001	0.468
Hope	520	0.515	0.185	0.583	0.225	< 0.001	0.330
Intent	519	0.612	0.211	0.692	0.217	< 0.001	0.374
Values	532	2.840	0.362	2.719	0.467	< 0.001	−0.290

Table 8
Comparison of Gains From the Pre-to the Post-Survey for Constructs of Participants Who Began the Simulation With More Communitarian-Egalitarian (CE) Values to Those With More Individualistic-Hierarchical (IH) Values

	CE			IH				
Variable	Mean	SD	N	Mean	SD	N	*p*-value	Effect size
Impacts	0.045	0.120	470	0.053	0.173	390	<0.001	0.055
Urgency	0.062	0.113	545	0.089	0.146	507	0.001	0.208
Hope	0.055	0.226	560	0.068	0.218	520	0.359	0.059
Intent	0.060	0.155	557	0.080	0.182	519	0.047	0.119

the tragedy of the commons (Hardin, 1968), with each delegation unwilling to cut emissions from its own nation or bloc that are necessary to meet international climate goals (Sterman et al., 2014). Participants learn that they cannot achieve climate goals without action from all delegations, setting up a challenge inherent in many collective action problems. They can only overcome this challenge if they work together and accommodate the needs of all parties, including developing nations that have done less to cause climate change but disproportionately bear its consequences. Recognition of nations' interdependence, reciprocity between parties, and cooperation support success in both the simulation and the real-world (Högle, 2018), while individualism and competition work against it. This experience may explain the shift towards communitarian-egalitarianism that we find among participants who begin the simulation with more individualistic-hierarchical values.

Throughout the simulation participants work to persuade others to take action on climate, creating a rich, shared social experience that is likely to be a key driver of *World Climate's* impact on climate change beliefs and attitudes. Research shows that discussing climate change with others is a key motivator of climate action (Campbell et al., 2021; Goldberg et al., 2019). Yet, only 35% of Americans discuss climate change with others, even occasionally (https://climatecommunication.yale.edu/visualizations-data/ycom-us/). Most people mistakenly assume that others are not concerned about climate change (Leviston et al., 2013). As a result, they are reluctant to share their own concerns about it, fearing that doing so would cause social dissonance (Geiger & Swim, 2016). The result is a vicious cycle: people avoid sharing their privately held concerns with others, causing others to underestimate the prevalence of those concerns, and further stifling conversations about climate change. Through its guided, structured role-play, *World Climate* helps break this cycle and create a shared sense of urgency about the problem. Many of these themes emerge in participants' open-ended comments, in which they describe seeing the

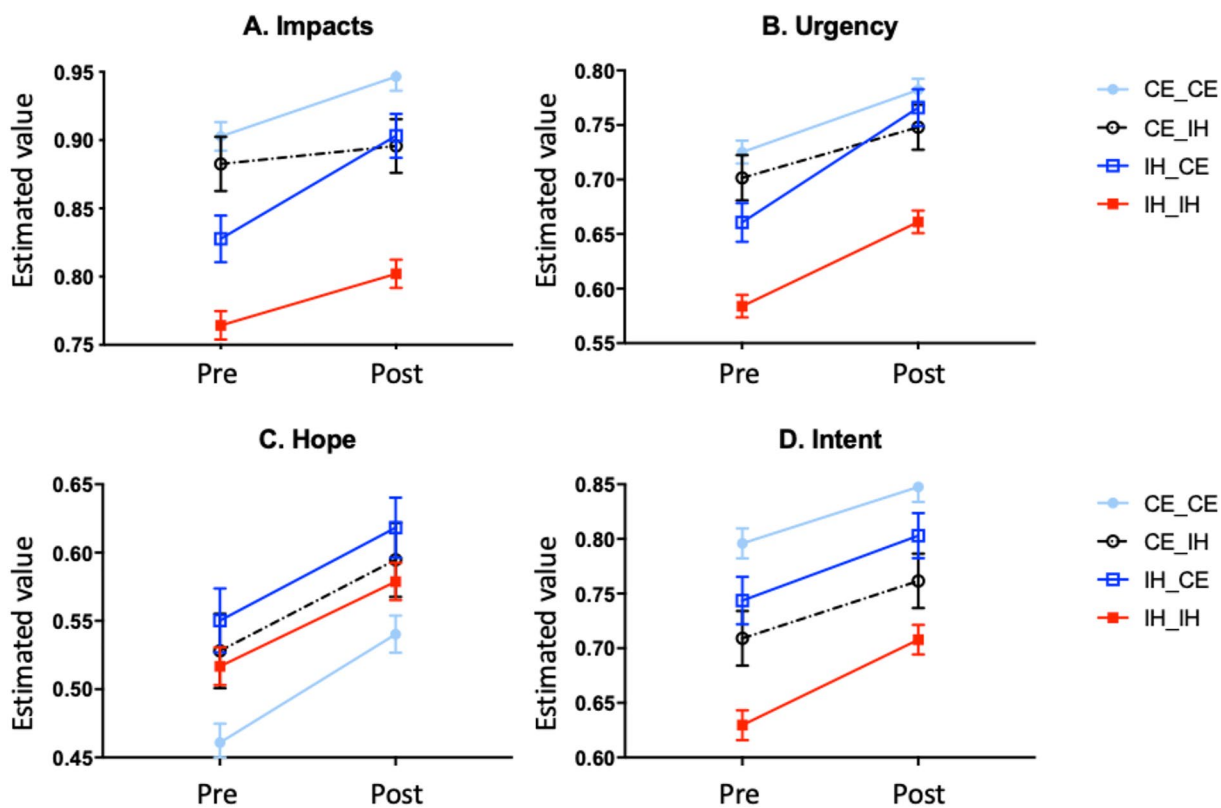

Figure 1. Estimated levels of climate change knowledge about impacts, sense of urgency and hope, and intent to act from general linear mixed models. Error bars show standard deviations. We divide participants into four groups based which sociopolitical category they fall into (i.e., communitarian-egalitarian or individualistic-hierarchical) pre- and post-simulation.

Table 9

Solutions for GLMM Fixed Effects for Knowledge About Impacts (A), Sense of Urgency (B), Hope (C), and Intent to act (D). "CE_CE" Refers to Participants Who Fell Into the Communitarian-Egalitarian (CE) Pre- and Post-Simulation; :CE_IH" Refers to Those Who Fell Into the CE Group Pre-Simulation and the Individualist-Hierarchical (IH) Group Post-Simulation; "IH_CE" Refers to Those Who Shift From IH to CE Pre-to Post-Simulation; 'IH_IH' Refers to Those Who Fall Within the IH Group Both Pre- and Post-Simulation

Effect	Group	Pre versus post	Estimate	SE	DF	T	*p*-value	Overall *p*-value[a]
A. Impacts.								
Group (Ref = IH_IH)	CE_CE		0.139	0.012	1,116	11.47	<0.001	<0.001***
	CE_IH		0.118	0.020	1,408	5.82	<0.001	
	IH_CE		0.063	0.018	1,450	3.57	<0.001	
Pre versus post (Ref = Pre)		Post	0.038	0.009	775	4.37	<0.001	<0.001***
Group * Pre versus post	CE_CE	Post	0.006	0.012	755	0.5	0.618	0.0978
	CE_IH	Post	−0.025	0.022	785	−1.12	0.265	<0.001***
	IH_CE	Post	0.038	0.019	770	2.01	0.045	
B. *Urgency*.								
Group (Ref = IH_IH)	CE_CE		0.141	0.013	755	10.97	<0.001	<0.001***
	CE_IH		0.118	0.022	1,269	5.42	<0.001	
	IH_CE		0.077	0.019	1,321	4.08	<0.001	
Pre versus post (Ref = Pre)		Post	0.077	0.008	735	10.17	<0.001	<0.001***
Group * Pre versus post	CE_CE	Post	−0.020	0.010	721	−1.96	0.050	0.0085**
	CE_IH	Post	−0.031	0.020	743	−1.59	0.113	
	IH_CE	Post	0.028	0.016	731	1.69	0.091	
C. *Hope*.								
Group (Ref = IH_IH)	CE_CE		−0.056	0.017	1,094	−3.34	0.001	<0.001***
	CE_IH		0.011	0.028	1,420	0.39	0.696	
	IH_CE		0.034	0.025	1,459	1.35	0.178	
Pre versus post (Ref = Pre)		Post	0.062	0.012	791	5.11	<0.001	<0.001***
Group * Pre versus post	CE_CE	Post	0.017	0.017	771	1.04	0.297	0.7713
	CE_IH	Post	0.005	0.031	802	0.15	0.880	
	IH_CE	Post	0.006	0.026	787	0.23	0.822	
D. *Intent*.								
Group (Ref = IH_IH)	CE_CE		0.166	0.015	1,109	10.96	<0.001	<0.001***
	CE_IH		0.079	0.025	1,318	3.14	0.002	
	IH_CE		0.114	0.022	1,371	5.18	<0.001	
Pre versus post (Ref = Pre)		Post	0.078	0.010	728	8.04	<0.001	<0.001***
Group * Pre versus post	CE_CE	Post	−0.027	0.013	711	−2	0.046	0.2353
	CE_IH	Post	−0.026	0.025	737	−1.03	0.304	
	IH_CE	Post	−0.019	0.021	723	−0.9	0.367	

Note: The IH_IH group serves as a reference ("Ref") against which other sociopolitical groups are compared, while post-survey values are compared to those from pre-surveys. Estimates of beta coefficients are provided. Fixed effects that are statistically significant are marked in the right-hand column (***$p < 0.001$, **$p < 0.01$, *$p < 0.05$).

[a]We provide the overall *p*-value for a type of fixed effect, that is pre versus post, sociopolitical group (Group), or the interaction between participating in the simulation and sociopolitical values group.

problem from new perspectives, a recognition that collective action was needed, and a willingness to advocate for change both within the simulation and in the real world. When they succeed in taking collective action, *World Climate* participants report feeling a sense of collective efficacy, which is considered an important predictor of climate action in the real world (Roser-Renouf et al., 2014).

4.1. The Role of Hope

Research indicates that hope plays an important role in climate change policy support (Smith & Leiserowitz, 2014), suggesting that it should also play an important role in climate change communication. The construct we refer to as *"Hope"* combines two survey items that ask participants how participants feel about climate change on scales spanning emotional poles from hopeless to hopeful and from discouraged to empowered (Osgood et al., 1957). Across all sociopolitical groups, participating in *World Climate* is associated with a statistically significant increase in the *Hope* construct (Table 5, Table 9). Furthermore, the greater participants' gains in *Hope*, the greater their gains in intent to take climate action and their desire to learn more about climate change (Rooney-Varga et al., 2018). Here, we find that individualistic-hierarchs begin and end the simulation with higher levels of *Hope*, but lower *Intent* than communitarian-egalitarians. This result is evident from GLMM analysis showing a statistically significant effect of sociopolitical group on *Hope* and, in particular, between CE_CE and IH_IH participants (Table 9c). These results raise a question about whether a sense of hope and empowerment spurs or deters science-based climate action.

Research shows hope about climate change has different underlying causes that may explain this apparent paradox. "Constructive hope" (Marlon et al., 2019; Ojala, 2015) is associated with active engagement with the issue and a sense that society can act together to address it. In contrast, "false hope" (Marlon et al., 2019) and "hope based on denial" (Ojala, 2015) downplay the risk of climate change or human agency over it, assuming that it is either not a consequential problem or that, even if it were, an external force (e.g., a supernatural force or nature) will solve it without human action. Both false hope and hope based on denial are negatively related to climate engagement (Marlon et al., 2019; Ojala, 2015). Here, we speculate that participants who began with a more dismissive view of the dangers posed by human-caused climate change were also more likely to hold a sense of "hope based on denial," while gains in *Hope* may reflect a more "constructive" feeling that society could engage and take concerted action. Further research should qualify the type of hope that spurs or discourages climate action. *World Climate* participants report that they gain a sense of collective efficacy through the simulation, as they work together to overcome barriers to climate action and achieve their desired climate goals in the simulation. Active problem-solving and working with others to address it can evoke a sense of hope that solutions to climate change are possible (Ojala, 2015). This study and others (Rooney-Varga et al., 2018, 2020; Sterman et al., 2014) suggest that *World Climate* and simulations like it can foster pro-climate emotions, intent, and action in the real world.

4.2. Limitations

In this study, we are not able to assign people randomly to participate in *World Climate* or some other activity (including nothing) as a control group. While we cannot rule out the possibility that some factor other than the simulation caused the pre-to post-simulation changes in participants' responses, the study design makes that unlikely. We minimize the potential impact of external events on participants' responses by (a) administering pre- and post-surveys immediately before and after the simulation and (b) analyzing results from 41 sessions held on different dates so that no single external climate-related event could affect pre-to post-survey shifts across sessions. Session dates are considered random effects in GLMMs and are therefore independent from the effect of the simulation (i.e., pre-vs. post-survey) on constructs. It is therefore not plausible that an external event caused the observed pre-to post-survey changes. In addition, sessions were run by different facilitators in different parts of the nation. We cannot, however, rule out priming effects from the pre-survey. A valuable extension of this research would be to randomly assign participants to a pre-survey or no pre-survey group.

Our sample was not randomly drawn from the general population and is therefore not expected to be representative of the American public. In addition, because the youngest participants in our study were drawn from programs serving low-income, first-generation-to-college students, age likely correlates with other demographic

traits in our sample. We therefore do not claim that the observed effects of the simulation or demographics extend to the general American population. However, tests for external validity do not raise concerns about response or selection bias. The observed pre-to post-simulation gains are therefore not limited to participants who elect to respond to surveys or participate in a climate change-related activity.

5. Conclusions

At the time of writing, the *World Climate* simulation has reached more than 77,000 participants in 98 countries in settings ranging from middle to graduate school, civic organizations, non-governmental organizations, businesses, the military, and governments. The approach of combining role-play with interactive, science-based computer models, appears to have great potential for depolarizing climate change and motivating science-based action. For example, initial evaluation indicates similar outcomes for the *Climate Action Simulation* (Rooney-Varga et al., 2020), in which participants take on the roles of leaders from key economic and governmental sectors to make climate policy decisions that they test in an interactive computer model, En-ROADS, which allows participants to choose a set of actions to reduce emissions (e.g., a carbon price, subsidies for nuclear or renewable energy, phase-outs of coal, afforestation, and many others). These tools are freely available online, are available in 14 languages, and can be used in face-to-face or virtual settings, offering potential for scaling and broad impact in the US and beyond.

Data Availability Statement

Datasets for this research are available in this in-text data citation reference (Rooney-Varga et al., 2021).

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