AMERICAN SOCIETY FOR MICROBIOLOGY | JMBE Journal of Microbiology & Biology Education

| Research Article

Place-based climate change: lowering students' psychological distance through a classroom activity

Jessica Duke,[1] **Emily A. Holt**[1]

AUTHOR AFFILIATION See affiliation list on p. 9.

ABSTRACT Psychological distance (PD) can be a barrier to how students perceive climate change impacts and severity. Localizing climate change using place-based approaches is one way instructors can structure their curricula to help combat students' PD, especially from a spatial and social viewpoint. We created a novel classroom intervention that incorporated elements of place-based education and the Teaching for Transformative Experiences in Science model that was designed to lower undergraduate biology students' spatial and social distance of climate change. Our research questions sought to determine whether students' PD changed following our intervention and whether variables beyond our intervention might have contributed to changes we identified. To measure the efficacy of our intervention, we administered a survey that contained several instruments to measure students' recognition and psychological distance of climate change pre- and post-intervention. We found that students' psychological distance to climate change decreased after participating in our classroom intervention. Additionally, course level was the only outside variable we identified as a predictor of students' post-activity scores. Participation in our activity lowered our students' spatial and social psychological distance, which could have impacts beyond the classroom as these students become the next generation of scientists and voters.

KEYWORDS climate change, education, classroom intervention, university students, biology, psychological distance, teaching for transformative experience (TTES)

The ever-present threat of climate change has increased the interest in and need for instructors to include climate change in undergraduate student curricula (1, 2). However, the global and interdisciplinary complexity of climate change can create barriers for instructors, making it difficult to incorporate the topic into their existing classroom curricula (2). In the classroom, instructors often frame climate change primarily within a global context, which can impact how students understand climate change and perceive its severity (3, 4). Further, this globalized framing can increase the distance in which students perceive the impacts of climate change (5, 6). The construct of psychological distance (PD) is often used to describe the perceived distance between an individual and climate change across multiple scales (e.g., spatial, social, temporal, and hypothetical) (7; Fig. 1). Individuals might experience one or multiple levels of psychological distance at any given time.

Increased psychological distance is considered a barrier to climate change action (8). Lowering a person's PD can lead to an elevated concern for climate change (4, 6, 9) and sometimes increased performance of sustainable actions and behaviors (10). Some research suggests that proximizing climate change, or making it more personally relevant, can lower an individual's psychological distance leading to increased concern and action (8, 11). However, other research indicates that simply personalizing climate change may not have the desired effect (12) and can sometimes lead to lowered concern for climate change (13). Prior beliefs regarding climate change may also contribute to the

Editor Arpita Bose, Washington University in St. Louis, St. Louis, Missouri, USA

Address correspondence to Jessica Duke, jessica.duke@unco.edu.

The authors declare no conflict of interest.

Received 10 October 2023
Accepted 1 March 2024
Published 22 March 2024

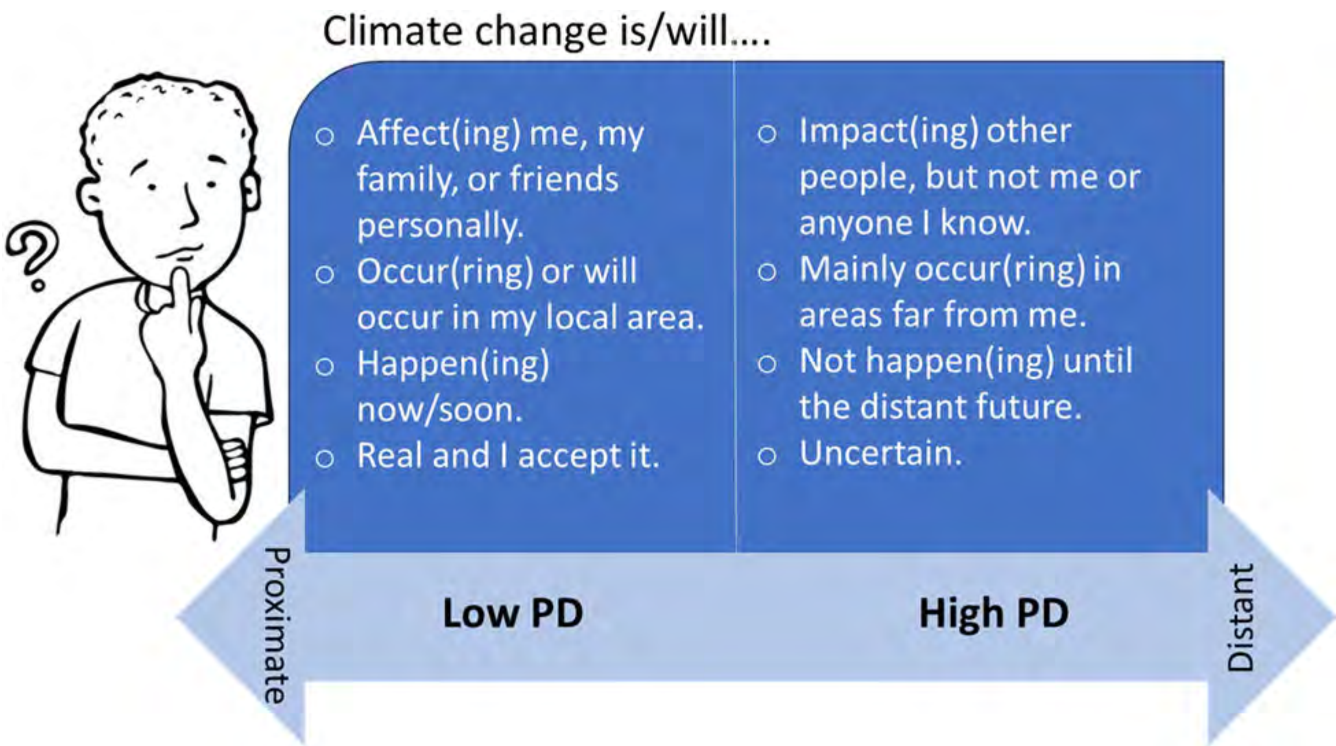

FIG 1 Figure depicting proximal versus distant levels of psychological distance.

decreased effect that proximizing climate change has on an individual (14). Additionally, intense experiences with climate-related disasters can lead to increased fear associated with climate change impacts leading some individuals to further distance themselves from climate change problems instead of increasing their concern or action (15).

Duke and Holt (16) found that university students who had lower levels of spatial psychological distance were more aware of localized effects of climate change and were able to provide observational examples suggesting that PD could be a valuable construct to utilize in educational settings. Furthermore, Gubler et al. (4) found that PD is an important predictor of climate change concern in student populations. Studies have shown that an individual's PD is not static and can change when new information is presented (17, 18). If true, targeting psychological distance through curricula and classroom activities could be an effective strategy for increasing students' concern for climate change.

Strategies to create personally relevant curricula are frequently discussed in the literature, especially in relation to climate change education (2, 5, 19, 20). Place-based education (PBE) is used to engage students in their local communities, including local environments, and is often targeted by instructors seeking to increase environmental awareness in their students (21, 22). In addition to PBE, the teaching for transformative experience model offers a way to further personalize climate change for students. The construct of transformative experience is rooted in the concept of personal relevance describing student experiences as “a learning episode in which a student acts on the subject matter by using it in everyday experience to more fully perceive some aspect of the everyday world and finds meaning in doing so” (23, p. 111). Meaningful student learning is achieved through genuine experiences that can be directly applied to the student's life, allowing more value to be placed upon the content learned (23, 24). Through these transformative experiences, students begin to see the content in new ways and use this new information to expand their perceptions of the phenomena of interest (25). There is limited research that uses these constructs (i.e., place-based education, TTES) in tandem to effectively personalize course curricula (26).

Research questions

Our study aimed to determine the efficacy of a purposefully designed classroom intervention to lower the spatial and social psychological distance of climate change among biology undergraduate students. To better localize climate change, our activity takes a novel approach by combining concepts from place-based education (PBE) and the Teaching for Transformative Experiences in Science (TTES) model. Our study included two key research questions. RQ 1: Following a classroom intervention, does biology students' spatial and social psychological distance (PD) associated with climate change change? RQ 2: What factors (political party, gender, other PD scales, etc.) best predict students' spatial and social PD?

METHODS

Data collection for this study was conducted with permission from the Institutional Review Board at the University of Northern Colorado where the primary investigators are affiliated (IRB No. 2208042211). We used convenience sampling (27) to recruit biology instructors from two higher education institutions in Colorado (CO) and Georgia (GA) to include our intervention in their classrooms in either the Fall 2022 or Spring 2023 semesters. We chose biology students because (1) we assumed these students would have a basic understanding of climate change and (2) previous research suggested that this population shows variance in their psychological distance to climate change (16).

Sites and participants

We contacted ten instructors across four institutions in CO and GA, and five of these instructors representing two institutions agreed to use our intervention in their classrooms and collect pre- and post-activity survey data (Table 1). All undergraduate biology students in recruited classes (*n = 685*) participated in a four-part classroom intervention in their respective course (lab, lecture, or hybrid setting; see *Climate Change Intervention Overview* for further details); however, only students who provided consent for the use of their data and those who completed both the pre- and post-surveys are included in the present study (*n* = 471). Consent was secured from each student participant before completing the pre- and post-intervention survey. Our final sample of 471 participants primarily resided in Georgia (*n* = 392), were sophomores (*n* = 128), identified as female (*n* = 309), and were white (*n* = 251) (Appendix S1).

Climate change intervention overview

This intervention (Appendix S3) specifically targets students' spatial and social psychological distance (PD) of climate change, with the goal of lowering students' PD across each scale (6, 7). We chose to target students' spatial PD because it was a significant predictor of students seeing the effects of localized climate change in another study (16). Next, we selected social PD because research suggests that students are often unaware of how climate change impacts humans, including themselves (3). Focusing

TABLE 1 Courses, states, and institutions from which participants were recruited[b]

Courses	Course level	Course taught	State	Institution[a]	Removed	Final sample size
Ecology	Advanced	Lab	CO	A1	12	31
Ecology	Advanced	Lab	CO	A2	3	34
Ecoclimatology	Advanced	Lecture	CO	A	12	14
Intro Biology II (majors)	Intro	Lab	GA	B	199	335
Ecology	Advanced	Hybrid	GA	B	6	57

[a]Numbers next to institution letters denote multiple sections of the same course.
[b]Multiple universities were sampled in each state and are anonymized and noted with letters. Some students were removed from the data set for incomplete surveys (*n* = 72), duplicate data (*n* = 21), completing the activity in multiple courses (*n* = 3), completing the pre-survey early (*n* = 13), or not consenting to their data being used in the study (*n* = 105). Sample size indicates the final sample from each course population after removals.

on spatial and social PD also allowed us to make our activity more localized, personally relevant, and meaningful to our student population by using place-based approaches to orient our intervention in the students' local area (2, 6, 19, 28). Finally, we incorporated elements of the TTES model to foster "reseeing" of climate change effects in our students' local environments (25, 29) and support our students' expansion of perception of how climate change affects their local areas (23).

The intervention is divided into three scaffolded activities, followed by small group share sessions, designed to address our research questions and student learning objectives (Appendix S3). Part 1 aimed to make climate change more personally relevant; students collaborated in small groups to explore local impacts of climate change on natural systems at different spatial scales and shared their findings with other groups. Part 2 targeted both spatial and social psychological distances and making climate change more personally relevant; students collaborated in small groups to explore local impacts of climate change on humans and shared their findings. Part 3 allowed students to "resee" and expand their perception of climate change effects on local communities. Through a campus walk, students predicted how climate change currently impacts their local environment currently and in the future.

Pre- and post-intervention survey

Since our RQ 1 sought to determine the impact of our intervention on students' social and spatial PD, participants were given an online pre-survey immediately before the activity and a post-survey the week following the activity. Students were awarded no compensation for sharing their data as part of the study. The pre- and post-surveys were identical to allow for comparison.

Our survey combined several validated instruments (Appendix S2) adapted from Spence et al. (6) and Gubler et al. (4), and we analyzed four of the scales for this study (Fig. 2). Each scale included several statements that were rated by students with a 5-level Likert scale, and then later consolidated through arithmetic averaging. The first two scales measured spatial PD and the latter two scales measured social PD. First, one of

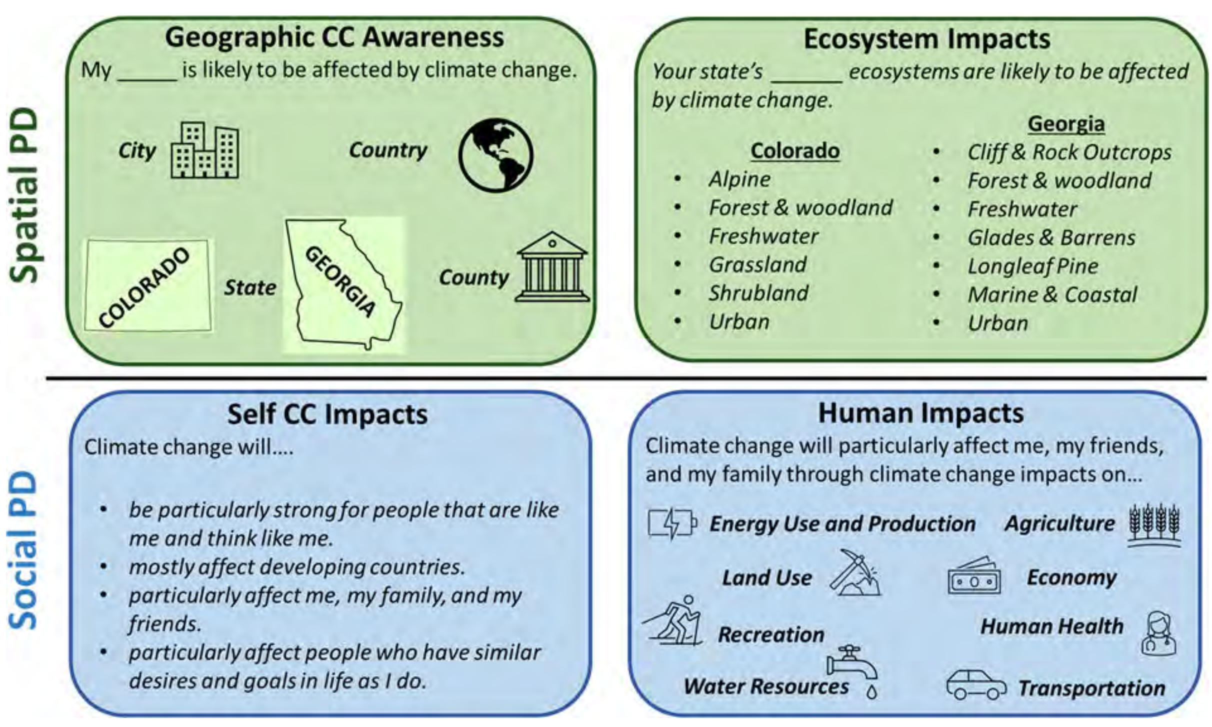

FIG 2 Four psychological distance scales included in our student pre- and post-survey. Each question was scored on a 5-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neither agree or disagree; 4 = agree; 5 = strongly agree).

the spatial scales we call the Geographic Climate Awareness Scale (GeoCC) was highly reliable with university students in a previous study (16), and our data were also highly reliable with this scale (Pre-Survey Cronbach's = 0.89; Post-Survey Cronbach's = 0.95).

Second, we created the Ecosystem Impacts of Climate Change Scale to measure spatial PD through a novel lens, focusing on whether students' perceived specific ecosystems in the state where their university is located are "likely to be impacted" by climate change. The ecosystems chosen for this scale were tailored to the state where the intervention was conducted (Fig. 2). The number of items on the ecosystem scale varied by location (CO = 6, GA = 7; Fig. 2). This novel scale was highly reliable for our population (EcoCC; CO Pre-Survey Cronbach's α = 0.90; CO Post-Survey Cronbach's α = 0.94; GA Pre-Survey Cronbach's α = 0.93; GA Post-Survey Cronbach's α = 0.95).

Next, we used two scales to capture social PD. Our third metric, which measured students' social PD, we called the Self Climate Change Impacts Scale (SelfCC; Pre-Survey Cronbach's = 0.76; Post-Survey Cronbach's α = 0.86). Finally, we created a Human Impacts of Climate Change Scale for social distance. This scale allowed us to further measure our students' social PD through a personal lens to determine how they (or their friends and family) have been impacted by climate change (e.g., economy, recreation; Fig. 2). This scale was also reliable for our population (HumCC; Pre-Survey Cronbach's α = 0.90; Post-Survey Cronbach's α = 0.96).

In the final section of the survey, we collected student information including gender, race/ethnicity, region, course level, academic level, political identity (e.g., conservative, liberal), and political party affiliation, most of which were collected to describe our population. Additionally, we hoped to seek general trends between the students' region of longest residence and their spatial and social PD of climate change. We provided students with a map of the United States and asked them to indicate the regional area where they have lived most of their lives (Appendix S2; Question #1).

Data analysis

Student data were deidentified prior to analysis. Most analyses were conducted using the statistical program R (30). Cronbach's α was utilized to determine the reliability of the psychological distance scales and was conducted using the "psych" package (31). Before choosing the statistical tests for our study, we ran a Shapiro-Wilk test and examined Q-Q plots, which indicated that our data did not follow a normal distribution ($P < 0.05$), so non-parametric tests were chosen to analyze our data. Further, many of our response variables and predictors were multicollinear; thus, we used models for which these are not an assumption. Each of the four scales measuring aspects of PD was analyzed as response variables in separate models. A Wilcoxon Signed Rank test helped identify paired differences in pre- and post-survey scores across each of our response variables. Effect sizes were calculated for any significant relationships ($P < 0.05$) using the "wilcox_effsize" function in the "coin" package in R (32).

To determine which factors (e.g., gender, political identity, other PD scales) best predicted scores on the PD scales, we performed non-parametric multiplicative regressions (NPMR) using HyperNiche version 2.0 (33). This regression type is primarily used for ecological modeling; however, its ability to model complex interactions using all possible combinations of factors is fitting for educational data (33). Each model fits a local mean using a Gaussian function and separate smoothing parameters or "tolerances", for each predictor (34). We conducted eight sets of NPMR models, two for each scale. For our first set of four models, we forced models for each scale with matched pre-survey scores as the sole predictor of post-survey score (e.g., GeoCC Pre as the only predictor of GeoCC Post scores; Table 2). These models served as proxies for the effect of our intervention on each participant's social and spatial PD. The second set of four models utilized the free-search function of HyperNiche that uses an iterative process to fit hundreds of potential models in a forward, stepwise manner (33, 34). For these models, we used post-survey scores as the response variable fitted against 10 possible predictors, including pre-survey scores for that scale, post-survey scores for the other

TABLE 2 Best-fit models included for each response variable[a]

Response type	Response variable	Intervention models (pre-only)		Best-fit models from nine possible predictors					Model comparison
		Variable	xR^2	Variable 1	Variable 2	Variable 3	Variable 4	xR^2	xR^2 difference
Post-Survey Models	GeoCC Post	GeoPre (0.20000)	0.3158	GeoPre (0.40000)	SelfPost (0.70000)	HumPost (0.40000)	EcoPost (0.60000)	0.5978	0.282
	SelfCC Post	SelfPre (0.35000)	0.2783	GeoPost (0.60000)	SelfPre (0.52500)	HumPost (0.40000)	N/A	0.4937	0.2154
	HumCC Post	HumPre (0.40000)	0.2936	SelfPost (0.35000)	HumPre (0.60000)	EcoPost (0.40000)	N/A	0.6131	0.3195
	EcoCC Post	EcoPre (0.40000)	0.2959	GeoPost (0.40000)	HumPost (0.20000)	Course (0.00000)	N/A	0.6449	0.349

[a]Each predictor variable is included with the tolerance included in parentheses

three scales, and six student factors (e.g., academic level, course level, gender, political affiliation, political identity, race/ethnicity, and region). We evaluated each model fit using a leave-one-out cross-validated pseudo-R^2 or xR^2, which helps reduce model overfitting (33, 34).

RESULTS

RQ 1: students' spatial and social psychological distance (PD) lowered following a classroom intervention

For both pre- and post-survey scores for the two spatial metrics (Geographic and Ecosystem scales), the interquartile range was primarily above 4 on a scale of 5 possible points suggesting fairly low spatial psychological distance in our sample (Fig. 3). Of the two social metrics, the interquartile ranges of the pre- and post-survey Human scale scores were lower than the spatial metrics but above 3 points, the mid-score value

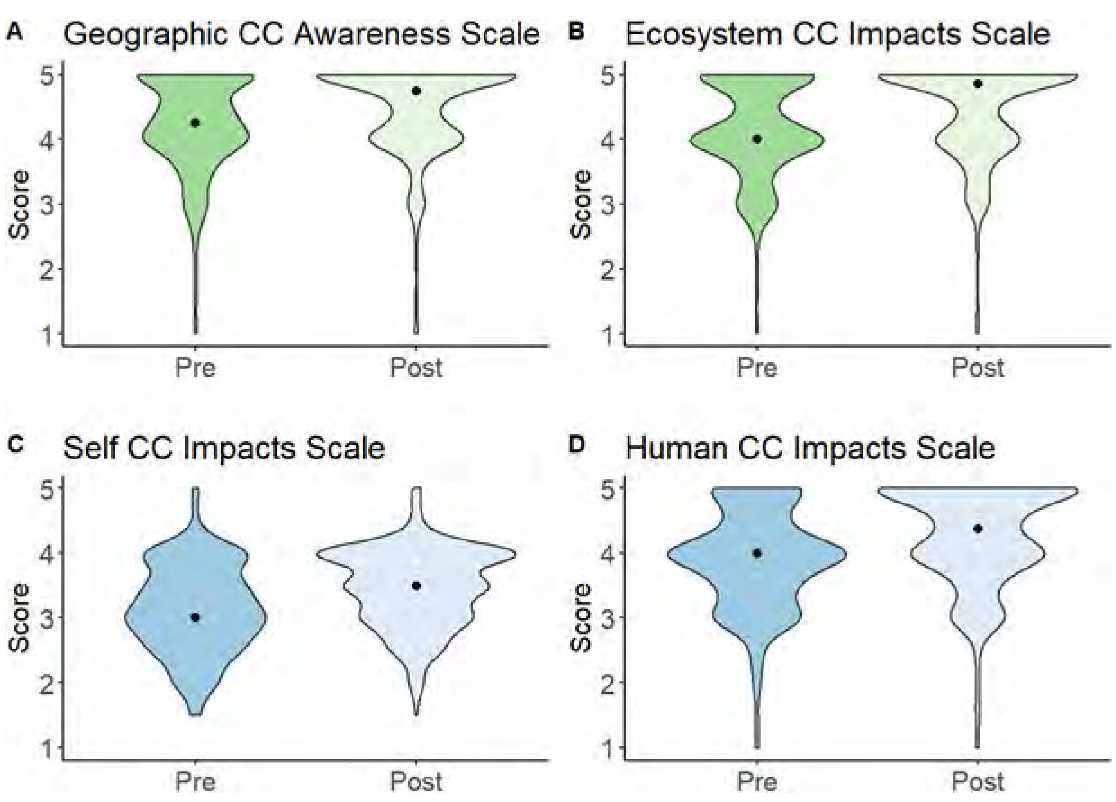

FIG 3 Violin plots of averaged categorical data from the two spatial metrics (Geographic and Ecosystem; green) and two social metrics (Self and Human; blue), separated by whether they were gathered prior to or following the climate change intervention. Figure 2 includes the items for each scale.

(Fig. 3). The other social metric, Self CC scale, had the lowest scores of the four scales (i.e., greatest PD; Fig. 3). Overall, participants scored higher on the post-survey across all four scales (i.e., lower PD following intervention). We found the paired difference in pre- and post-scores for each scale significantly differed from zero. Both spatial metrics (Geographic: $P < 0.001$, d = 0.39; Ecosystem: $P < 0.001$, d = 0.45) and the Self scale of the social metrics ($P < 0.001$, d = 0.48) had moderate effect sizes of this difference (*sensu*; 35). The Human scale of the social metrics ($P < 0.001$, d = 0.52) had a large effect size, where PD was reduced following the intervention (i.e., higher scale scores on post-surveys).

RQ 2: what factors contribute to differences in students' spatial and social PD?

The pre-scores only models explained ≥27% of the variance in each model (Table 2). Our best-fit free-search models for each of the four metrics explained ≥49% of the variance in each scale (Table 2). The four models with any possible predictors explained roughly two times as much variance in each scale as the pre-scores only models (Table 2). The best predictors in the free-search models included post-scores of other scales and pre-scores of that scale, excepting the Ecosystem CC scale (Table 2). Course level, which separated the introductory biology students from those in advanced biology courses, was the only student variable included as a predictor in the best-fit models of all predictors and was only included in the Ecosystem CC free-search model (Table 2).

DISCUSSION

Individuals with lower psychological distance to climate change are often more concerned about climate change (4, 6, 9), have increased environmental awareness (16), and sometimes perform more environmentally responsible behaviors (10, 11, 15). Our biology undergraduate sample generally had moderate to low spatial and social psychological distance to climate change at the start of the semester, suggesting that these students had some understanding of how climate change impacts local human and natural environments prior to participating in our intervention. Following participation, we found positive, significant increases in students' PD scale scores, i.e., reductions in their PD with time when compared to their pre-intervention scores (Fig. 3).

Research indicates that using visuals and maps, as used in our study, is important for communicating climate change and, when effective, can help to localize climate change, potentially leading to increased concern and engagement (19, 36, 37). After completing the intervention, we saw a decrease in students' spatial and social PD, which indicates an effective localization of climate change for our participants. Other studies have used different educational approaches in lowering PD through inquiry-based learning (38) and gamification (39, 40). Notably, Fox et al. (40) had university students complete an activity focusing on human-induced environmental impacts (e.g., pollution and illegal dumping) on rivers using an interactive video game and found that students who interacted with local rivers in the activity experienced a decrease in their spatial and temporal distance to their local environment. In our study, we saw a similar decrease in students' spatial distance associated with local ecosystems (Fig. 3), suggesting an increase in their environmental awareness of climate change impacts at the local level.

We noted the most significant pre- to post-survey increase and effect size for our Human PD scale following our classroom intervention (Fig. 3). Before our intervention, most of our university students exhibited moderate social PD that decreased following participating in our activity. With younger students, Gubler et al. (4) found that, while some middle and high school students were aware that climate change was directly impacting them, the majority believed that the effects would impact people in other locations. Personal experiences with climate change effects can reduce an individual's social distance, increasing their concern and understanding of risk (41, 42). These personal experiences develop over time, which might explain the higher social PD that Gubler et al. (4) observed. The relatively high average student score on the Human PD scale (i.e., moderate social PD) suggests that some of our students may already have personal experiences (i.e., recent destructive wildfires in CO) with climate change that they were able to recall during the pre-survey (Fig. 3). Although many students in our study initially acknowledged that they are affected by climate change, they may have been unsure of the details or severity of these impacts (6, 40). Our intervention may have helped solidify these personal experiences by filling in knowledge gaps, resulting in increased post-survey scores (i.e., decreased social PD).

Our NPMR models indicated that matched pre- and post-scores from different scales were better predictors of PD than other student variables (e.g., political identity, gender). While other research has indicated that demographic variables such as gender (43, 44), political party (45, 46), and geographic location (16, 47) are important predictors of climate change acceptance, awareness, and concern among individuals, we did not observe this relationship in our data. Of the five student variables included in our NPMR models, only Course Level was a strong predictor and it only manifested in one model as the third predictor after two others (e.g., EcoCC Post; Table 2). The Ecosystem CC scale focuses on how different ecosystems in the participants' state are impacted by climate change, which may be challenging for introductory-level biology students whose post-scores were generally lower than those of advanced biology students because they may not have yet developed strong ecological literacy (48). Alternatively, our ecology students' pre-Ecosystem CC scores were relatively high but their change over time may be limited by a ceiling effect (49, 50). Overall, our results are encouraging and suggest that regardless of most student characteristics we measured (academic level, gender, political identity, race/ethnicity, and region), students' PD was positively impacted by our intervention.

Limitations

While our results are promising, we acknowledge several limitations of our study. As mentioned above, some researchers indicate that different measures of PD (e.g., spatial, social, temporal, hypothetical) overlap and are difficult to disentangle (15). We recognize this overlap and indicate its presence in our results; however, this synergy between spatial and social PD does not detract from the cumulative reduction in PD across scales nor its overall importance in student perception at the local level. We also recognize that our limited participant demographics including geographic spread (i.e., most of our participants reside in the southern US) may limit the generalizability of our findings. Future research is needed to determine if comparable patterns exist in other student populations.

Conclusions

Our results indicate that students' spatial and social PD associated with climate change can change following classroom instruction. This fluidity suggests that PD is a valuable construct for instructors to target through curricular design (17, 18). The ability for students to understand that climate change effects are localized and capable of impacting them, their friends, and their families could be an important step in increasing concern for climate change and willingness to act sustainably to mitigate its effects (6, 9, 51); however, these relationships are complicated and not always present (9–12, 52). Regardless, our study indicates that lowering PD can increase students' spatial and social awareness of climate change at a local level, which could have important educational implications. While our findings suggest a change in students' PD, we cannot speculate on the prolonged nature of this change nor whether this change will lead to action to mitigate climate change. More research is needed to determine whether participating in our classroom intervention results in a lasting change in students' spatial and social PD, increases their climate change concern, and leads to more sustainable actions by students.

ACKNOWLEDGMENTS

We would like to acknowledge and thank the course instructors who agreed to implement our activity in their classrooms including Mario Bretfeld, Beverly Collins, Victoria Duncan, Scott Franklin, and Dovid Kozlovsky and the graduate teaching assistants who served as laboratory instructors during our implementation. Additionally, we would like to thank the student participants for completing the activity and agreeing to take part in our study. Finally, we would like to thank the Division of Academic Effectiveness at the University of Northern Colorado for an Assessment Mini-Grant to develop the novel activity examined in this study.

This study was partially supported by an Assessment Mini-Grant from the Division of Academic Effectiveness at the University of Northern Colorado.

AUTHOR AFFILIATION

[1]Department of Biological Sciences, University of Northern Colorado, Greeley, Colorado, USA

AUTHOR ORCIDs

Jessica Duke http://orcid.org/0000-0003-0895-0265
Emily A. Holt http://orcid.org/0000-0002-1777-7882

AUTHOR CONTRIBUTIONS

Jessica Duke, Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review and editing | Emily A. Holt, Conceptualization, Formal analysis, Investigation, Project administration, Resources, Supervision, Writing – review and editing

ADDITIONAL FILES

The following material is available online.

Supplemental Material

Appendix S1 (jmbe00168-23-s0001.pdf). Appendix S1 - student demographics.
Appendix S2 (jmbe00168-23-s0002.pdf). Appendix S2 - pre-/post-student survey.
Appendix S3 (jmbe00168-23-s0003.pdf). Appendix S3 - student climate change activity.

REFERENCES

1. IPCC. 2021. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change. In Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R, Zhou B (ed), Climate change 2021: the physical science basis. Cambridge University Press, Cambridge, United Kingdom, New York, USA, In press.
2. Monroe MC, Plate RR, Oxarart A, Bowers A, Chaves WA. 2019. Identifying effective climate change education strategies: a systematic review of the research. Environ Educ Res 25:791–812. https://doi.org/10.1080/13504622.2017.1360842
3. Busch KC. 2016. Polar bears or people? Exploring ways in which teachers frame climate change in the classroom. Int J Sci Educ B Commun Public Engagem 6:137–165. https://doi.org/10.1080/21548455.2015.1027320
4. Gubler M, Brügger A, Eyer M. 2019. Adolescents' perceptions of the psychological distance to climate change, its relevance for building concern about it, and the potential for education, p 129–147. In Filho WL, Hemstock SL (ed), Climate change and the role of education. Springer Nature Switzerland AG, Cham, Switzerland.
5. Devine-Wright P. 2013. Think global, act local? The relevance of place attachments and place identities in a climate changed world. Glob Environ Change 23:61–69. https://doi.org/10.1016/j.gloenvcha.2012.08.003
6. Spence A, Poortinga W, Pidgeon N. 2012. The psychological distance of climate change. Risk Anal 32:957–972. https://doi.org/10.1111/j.1539-6924.2011.01695.x
7. Trope Y, Liberman N. 2010. Construal-level theory of psychological distance. Psychol Rev 117:440–463. https://doi.org/10.1037/a0018963
8. Van Lange PAM, Huckelba AL. 2021. Psychological distance: how to make climate change less abstract and closer to the self. Curr Opin Psychol 42:49–53. https://doi.org/10.1016/j.copsyc.2021.03.011
9. Busch KC, Ayala Chávez R. 2022. Adolescent framings of climate change, psychological distancing, and implications for climate change concern and behavior. Clim Change 171:3–4. https://doi.org/10.1007/s10584-022-03349-4
10. Maiella R, La Malva P, Marchetti D, Pomarico E, Di Crosta A, Palumbo R, Cetara L, Di Domenico A, Verrocchio MC. 2020. The psychological distance and climate change: a systematic review on the mitigation and adaptation behaviors. Front Psychol 11:568899. https://doi.org/10.3389/fpsyg.2020.568899

11. Loy LS, Spence A. 2020. Reducing, and bridging, the psychological distance of climate change. J Environ Psychol 67:101388. https://doi.org/10.1016/j.jenvp.2020.101388
12. Brügger A, Morton TA, Dessai S. 2016. Proximising" climate change reconsidered: a construal level theory perspective. J Environ Psychol 46:125–142. https://doi.org/10.1016/j.jenvp.2016.04.004
13. Mildenberger M, Lubell M, Hummel M. 2019. Personalized risk messaging can reduce climate concerns. Glob Environ Change 55:15–24. https://doi.org/10.1016/j.gloenvcha.2019.01.002
14. Halperin A, Walton P. 2018. The importance of place in communicating climate change to different facets of the American public. Weather Clim Soc 10:291–305. https://doi.org/10.1175/WCAS-D-16-0119.1
15. McDonald RI, Chai HY, Newell BR. 2015. Personal experience and the 'psychological distance' of climate change: an integrative review. J Environ Psychol 44:109–118. https://doi.org/10.1016/j.jenvp.2015.10.003
16. Duke JR, Holt EA. 2022. Seeing climate change: psychological distance and connection to nature. Environ Educ Res 28:949–969. https://doi.org/10.1080/13504622.2022.2042205
17. Chu H. 2022. Construing climate change: psychological distance, individual difference, and construal level of climate change. Environ Commun 16:883–899. https://doi.org/10.1080/17524032.2022.2061027
18. Keller E, Marsh JE, Richardson BH, Ball LJ. 2022. A systematic review of the psychological distance of climate change: towards the development of an evidence-based construct. J Environ Psychol 81:101822. https://doi.org/10.1016/j.jenvp.2022.101822
19. Scannell L, Gifford R. 2013. Personally relevant climate change: the role of place attachment and local versus global message framing in engagement. Environ Behav 45:60–85. https://doi.org/10.1177/0013916511421196
20. Devine-Wright P, Batel S. 2017. My neighbourhood, my country or my planet? The influence of multiple place attachments and climate change concern on social acceptance of energy infrastructure. Glob Environ Change 47:110–120. https://doi.org/10.1016/j.gloenvcha.2017.08.003
21. Schild R. 2016. Environmental citizenship: what can political theory contribute to environmental education practice? J Environ Educ 47:19–34. https://doi.org/10.1080/00958964.2015.1092417
22. Yemini M, Engel L, Ben Simon A. 2023. Place-based education - a systematic review of literature . Educ Rev:1–21. https://doi.org/10.1080/00131911.2023.2177260
23. Pugh KJ. 2011. Transformative experience: an integrative construct in the spirit of deweyan pragmatism. Educ Psychol 46:107–121. https://doi.org/10.1080/00461520.2011.558817
24. Hickman L. 2009. John Dewey: His life and work, p 3–18. In Hickman L, Neubert S, Reich K (ed), John Dewey between pragmatism and Constructivism. Fordham University Press, New York, NY.
25. Pugh KJ, Bergstrom CM, Heddy BC, Krob KE. 2017. Supporting deep engagement: the teaching for transformative experiences in science (TTES) model. J Exp Educ 85:629–657. https://doi.org/10.1080/00220973.2016.1277333
26. Littrell MK, Gold AU, Koskey KLK, May TA, Leckey E, Okochi C. 2022. Transformative experience in an informal science learning program about climate change. J Res Sci Teach 59:1010–1034. https://doi.org/10.1002/tea.21750
27. Creswell JW, Plano Clark VL. 2017. Designing and conducting mixed methods research. 3rd ed. SAGE Publications, New York.
28. Clayton S, Luebke J, Saunders C, Matiasek J, Grajal A. 2014. Connecting to nature at the zoo: implications for responding to climate change. Environ Educ Res 20:460–475. https://doi.org/10.1080/13504622.2013.816267
29. Pugh KJ. 2020. Transformative science education: change how your students experience the world. Teachers College Press, New York.
30. R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.R-project.org/
31. Revelle W. 2020. Psych: Procedures for personality and psychological research. Northwestern University, Evanston, IL. Available from: https://CRAN.R-project.org/package=psych Version = 2.1.3
32. Hothorn T, Hornik K, van de Wiel MA, Zeileis A. 2006. A Lego system for conditional inference. Am Stat 60:257–263. https://doi.org/10.1198/000313006X118430
33. McCune B, Mefford MJ. 2009. HyperNiche. Nonparametric multiplicative habitat modeling. Version 2.0. MjM Software, Gleneden Beach, OR.
34. McCune B. 2006. Non‐parametric habitat models with automatic interactions. J Veg Sci 17:819–830. https://doi.org/10.1111/j.1654-1103.2006.tb02505.x
35. Sullivan GM, Feinn R. 2012. Using effect size-or why the *P* value is not enough. J Grad Med Educ 4:279–282. https://doi.org/10.4300/JGME-D-12-00156.1
36. O'Neill S, Nicholson-Cole S. 2009. Fear won't do it: promoting positive engagement with climate change through visual and Iconic representations. Sci Commun 30:355–379.
37. Retchless DP. 2018. Understanding local sea level rise risk perceptions and the power of maps to change them: the effects of distance and doubt. Environ Behav 50:483–511. https://doi.org/10.1177/0013916517709043
38. Brumann, S, Ohl, U, Schackert, C 2019. Researching climate change in their own backyard—inquiry-based learning as a promising approach for senior class students, p 71-86. In Filho, WL, Hemstock, SL (ed), Climate change and the role of education, Springer Nature Switzerland AG, Cham, Switzerland.
39. Fauville G, Queiroz ACM, Bailenson JN. 2020. Virtual reality as a promising tool to promote climate change awareness. Technol Health Care 91. https://doi.org/10.1016/B978-0-12-816958-2.00005-8
40. Fox J, McKnight J, Sun Y, Maung D, Crawfis R. 2020. Using a serious game to communicate risk and minimize psychological distance regarding environmental pollution. Telemat Inform 46:101320. https://doi.org/10.1016/j.tele.2019.101320
41. Akerlof K, Maibach EW, Fitzgerald D, Cedeno AY, Neuman A. 2013. Do people "personally experience" global warming, and if so how, and does it matter? Glob Environ Change 23:81–91. https://doi.org/10.1016/j.gloenvcha.2012.07.006
42. Spence A, Poortinga W, Butler C, Pidgeon NF. 2011. Perceptions of climate change and willingness to save energy related to flood experience. Nat Clim Chang 1:46–49. https://doi.org/10.1038/nclimate1059
43. McCright AM. 2010. The effects of gender on climate change knowledge and concern in the American public. Popul Environ 32:66–87. https://doi.org/10.1007/s11111-010-0113-1
44. Stevenson KT, Peterson MN, Bondell HD, Moore SE, Carrier SJ. 2014. Overcoming skepticism with education: interacting influences of worldview and climate change knowledge on perceived climate change risk among adolescents. Clim Change 126:293–304. https://doi.org/10.1007/s10584-014-1228-7
45. Hess DJ, Maki A. 2019. Climate change belief, sustainability education, and political values: Assessing the need for higher-education curriculum reform. J Clean Prod 228:1157–1166. https://doi.org/10.1016/j.jclepro.2019.04.291
46. McCright AM, Dunlap RE. 2011. The politicization of climate change and polarization in the American public's views of global warming, 2001–2010. Sociol Q 52:155–194.
47. Poortinga W, Whitmarsh L, Steg L, Böhm G, Fisher S. 2019. Climate change perceptions and their individual-level determinants: a cross-European analysis. Glob Environ Change55:25–35. https://doi.org/10.1016/j.gloenvcha.2019.01.007
48. Lewinsohn TM, Attayde JL, Fonseca CR, Ganade G, Jorge LR, Kollmann J, Overbeck GE, Prado PI, Pillar VD, Popp D, da Rocha PLB, Silva WR, Spiekermann A, Weisser WW. 2015. Ecological literacy and beyond: problem-based learning for future professionals. Ambio 44:154–162. https://doi.org/10.1007/s13280-014-0539-2
49. Šimkovic M, Träuble B. 2019. Robustness of statistical methods when measure is affected by ceiling and/or floor effect. PLoS One 14:e0220889. https://doi.org/10.1371/journal.pone.0220889
50. Cramer D, Howitt DL. 2004. The SAGE dictionary of statistics. SAGE Publications, Inc, Thousand Oaks, CA.
51. Evans L, Milfont TL, Lawrence J. 2014. Considering local adaptation increases willingness to mitigate. Glob Environ Change 25:69–75. https://doi.org/10.1016/j.gloenvcha.2013.12.013
52. Brügger A, Dessai S, Devine-Wright P, Morton TA, Pidgeon NF. 2015. Psychological responses to the proximity of climate change. Nature Clim Change 5:1031–1037. https://doi.org/10.1038/nclimate2760