LETTERS
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Children can foster climate change concern among their parents

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The collective action that is required to mitigate and adapt to climate change is extremely difficult to achieve, largely due to socio-ideological biases that perpetuate polarization over climate change[1,2]. Because climate change perceptions in children seem less susceptible to the influence of worldview or political context[3], it may be possible for them to inspire adults towards higher levels of climate concern, and in turn, collective action[4]. Child-to-parent intergenerational learning—that is, the transfer of knowledge, attitudes or behaviours from children to parents[5]—may be a promising pathway to overcoming socio-ideological barriers to climate concern[5]. Here we present an experimental evaluation of an educational intervention designed to build climate change concern among parents indirectly through their middle school-aged children in North Carolina, USA. Parents of children in the treatment group expressed higher levels of climate change concern than parents in the control group. The effects were strongest among male parents and conservative parents, who, consistent with previous research[1], displayed the lowest levels of climate concern before the intervention. Daughters appeared to be especially effective in influencing parents. Our results suggest that intergenerational learning may overcome barriers to building climate concern.

Minimizing climate change impacts requires immediate collective action. The recent IPCC report suggests that swift collective action (for example, a 45% decrease in global carbon emissions by 2030) is necessary to avoid catastrophic impacts, which include around 0.76 m of sea-level rise that will flood some island nations, 10% loss of available land for farming, increased storm frequency and intensity causing projected hundreds of trillions of dollars in damage, and loss of human life[6]. However, polarization over climate change persists, particularly in the United States[1,7], and levels of concern over climate change do not seem to match the severity of the imminent impacts[7]. For instance, only 54% of adults globally believe in anthropogenic climate change[8]. Similarly, 28% of Americans believe that there is a high degree of uncertainty around climate change causes and impacts[7], and that the effects of climate change will be isolated to developing nations[7,9]. This disengagement and disbelief is an issue for concern, as climate change concern is a key predictor of individual and collective action[4].

Several socio-ideological drivers help to explain the lack of climate change concern and associated collective action. Political ideology is consistently one of the major drivers of perceptions of climate change[1], despite direct personal experiences (for example, with extreme weather[7,10]) or scientific literacy[2]. Political ideology influences both the information received about climate change (for example, socio-ideologically framed newscasts[11]) and how it is interpreted (for example, accepting only socio-ideologically compatible information[12]). Similarly, conservative males consistently display low concern and high scepticism around climate change[13]. Like political ideology, gender is relatively stable once formed and reflects cultural constructs that shape how individuals interact with the world[13]. As these characteristics that influence one's climate change perceptions are engrained in personal identity, they are difficult, if not impossible, to change. Consequently, patterns of climate change concern have not mirrored the increasing threats of climate change.

A suite of strategic communication tools have emerged aiming to foster climate change concern among socio-ideologically diverse audiences. Strategic framing[14] has frequently been used to create climate change messages that are socio-ideologically compatible with diverse audiences. For example, stewardship frames have been used among evangelical Christian groups to align mitigation efforts with core Christian values[15]. Similarly, popular icons and trusted messengers are used to signal that climate change mitigation conforms to social norms[14]. Celebrities such as Leonardo DiCaprio are commonly seen in climate change messaging in hopes that those who like a specific celebrity will agree with their climate change views[12]. Although these communication strategies are helpful, their impacts are isolated to relatively narrow contexts[12,14,15], suggesting a need for additional communication strategies—ideally ones that are able to engage more citizens irrespective of their personal ideology or identity.

Intergenerational learning (IGL) represents an understudied but promising pathway for building climate change concern among citizens irrespective of their socio-ideological differences. As adolescents learn about climate change, they are less influenced by socio-ideological factors than adults are [3,16]. Although climate change communication and education campaigns have mixed or even polarizing results among adults[12], climate change education promotes climate change concern and mitigation behaviours among children[17]. Further, children influence their parents on a range of socio-ideologically fraught topics (for example, sexual orientation[18]); therefore, children may be able to make similar inroads with climate change[5]. Given the special relationship children have with parents, they may even be able to transcend socio-ideological barriers to climate change concern[5].

In an experimental study in coastal North Carolina (Supplementary Note 1 and Supplementary Fig. 1) we investigated

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Table 1 | Regression model results of child change in climate concern on pre-test scores, treatment group and control variables, including a random effect for teacher

	Child change in climate concern		
Variable	Unstandardized beta coefficient	s.e.m.	Standardized beta coefficient
Pre-test child climate concern score[a]	−0.375***	0.071	−0.300
Treatment[b]	1.552**	0.475	0.135
Year[c]	−0.801	0.503	−0.092
Child sex[d]	0.270*	0.561	0.133
Child race[e]	−0.070	0.480	−0.007
Constant[f]	0.992		
N	292		
R^2	0.110		
Rho teacher[g]	0.001		

Year one data were collected during autumn 2016 and spring 2017. Year two data were collected during autumn 2017 and spring 2018. [a]Climate change concern is a range from −8 (least concerned) to +8 (most concerned). [b]Treatment: 1 = treatment and 0 = control. [c]Year: 1 = year two and 0 = year one. [d]Sex: 1 = female and 0 = male. [e]Race: 1 = people of colour and 0 = white. [f]Y-intercept. [g]Rho is the proportion of residual variance explained by the teacher random effect. *$P<0.05$, **$P<0.01$ and *** $P<0.001$.

Table 2 | Regression model results of parent change in climate concern on pre-test scores, treatment groups, child change in climate concern, control variables and family dynamics interactions, including a nested random effect for teacher and family

	Parent change in climate concern		
Variable	Unstandardized beta coefficient	s.e.m.	Standardized beta coefficient
Pre-test parent climate concern score[a]	−0.244***	0.042	−0.310
Treatment[b]	1.567**	0.412	0.217
Child change in climate concern	0.815**	0.156	0.140
Control variables			
Level of family climate change discussion[c]	0.400*	0.040	0.120
Year[d]	0.119*	0.021	0.101
Child sex[e]	0.269*	0.102	0.109
Parent sex[e]	−0.674*	0.337	−0.104
Child race[f]	0.015	0.120	0.008
Parent race[f]	0.387	0.184	0.047
Conservative parents[g]	−0.312	0.153	−0.062
Family dynamics interactions			
Child change in climate change concern × conservative parents	0.122*	0.069	0.099
Child change in climate change concern × parent sex	0.108*	0.101	0.074
Child change in climate change concern × child sex	0.239*	0.170	0.061
Constant	2.486		
N	289		
R^2	0.297		
Rho teacher	0.0025		
Rho family	0.0018		

Data were collected during autumn 2016, spring 2017, autumn 2017 and spring 2018. [a]Climate change concern is a range from −8 (least concerned) to +8 (most concerned). [b]Treatment: 1 = treatment and 0 = control. [c]Level of family climate change discussion: 1 = never to 5 = three times or more. [d]Year: 1 = year two and 0 = year one. [e]Sex: 1 = female and 0 = male. [f]Race: 1 = people of colour and 0 = white. [g]Conservative parents: 1 = conservative 0 = moderate or liberal. *$P<0.05$, **$P<0.01$ and ***$P<0.001$.

the potential of IGL in a climate change-specific context. We randomly assigned 15 participating teachers to treatment and control groups, trained them in a climate change curriculum specifically designed to promote IGL (Methods), and measured impacts on students and their parents over two years ($n=11$ treatment groups, 12 control groups) (Supplementary Fig. 2). The curriculum consisted of four classroom activities and a field-based service-learning project, as well as an interview with parents (see Supplementary Table 1). We used matched household-level survey data of 238 families consisting of one or two parents (referring to biological parents, foster parents, grandparents and/or guardians), and middle school children (aged 10–14 yr old). We examined changes in parents' climate change concern as a function of membership in the treatment group, as mediated by changes in children's concern using sequential multiple linear regression modelling. Additionally, we controlled for how much families talked about climate change, child and parent gender, child and parent race, and parent political ideology to understand how IGL may operate across diverse family dynamics and demographics among both adults and children and included random effects for both teacher and family.

Our results include four major findings. First, children who participated in our curriculum showed larger increases in climate change concern than students in the control group (2.05 points more than the control group on a 16-point concern scale; s.d. = 1.38), which was a significant difference when control variables were held constant (Table 1; $P=0.009$; Cohen's $f^2=0.122$). Second, children in the treatment group fostered more climate change concern among their parents than was the case for the control group (an average of 4.29 points more; s.d. = 2.87; Table 2; $P=0.006$; Cohen's $f^2=0.422$). This difference persisted even though concern for climate change increased during the test period among parents in both the treatment and control groups (Supplementary Note 2). The curriculum did not include any direct interactions with adults, suggesting that the transfer occurred through children. Third, changes in parents' climate change concern were most pronounced among the groups that are typically most resistant to climate change communication. Specifically, politically conservative parents who had the lowest concern levels before the intervention displayed the largest gains in climate change concern associated with IGL facilitated by their children (Table 2 and Fig. 1; $P=0.032$; Cohen's $f^2=0.326$), and fathers displayed greater gains in climate change concern than mothers (Table 2 and Fig. 2; $P=0.043$; Cohen's $f^2=0.158$). Fourth, daughters were more effective than sons in fostering climate change concern among their parents (Table 2 and Fig. 3; $P=0.041$; Cohen's $f^2=0.182$).

The success of climate change education with adolescents may reflect an age-related window of influence. Although children are capable of understanding complex subjects like climate change[19], they still retain a level of plasticity in their opinions as they make sense of the world around them[20]. For instance, it is only at low levels of climate change understanding that worldviews function as an information filter for children when forming climate change perceptions[3]. Furthermore, recent research has demonstrated a causal link between climate change education targeted at adolescents and knowledge gain, which in turn was linked to behaviour change[17]. As adult climate change perceptions appear to be stable across multiple

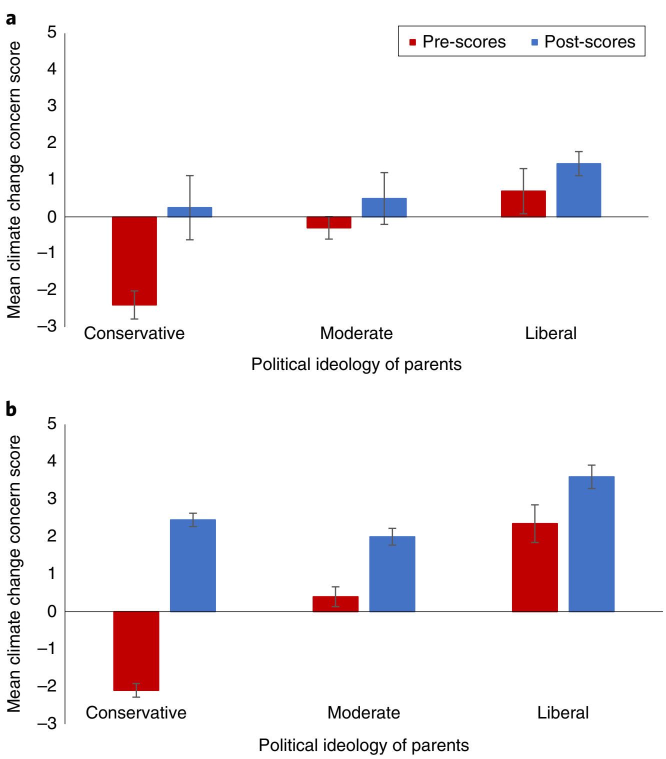

Fig. 1 | Parent climate change concern as a function of political ideology. **a**,**b**, Mean climate change concern scores based on political ideology of parents in the control (**a**; $n=92$) and treatment (**b**; $n=196$) groups before (pre-test) and after (post-test) treatment. Error bars show 95% confidence interval.

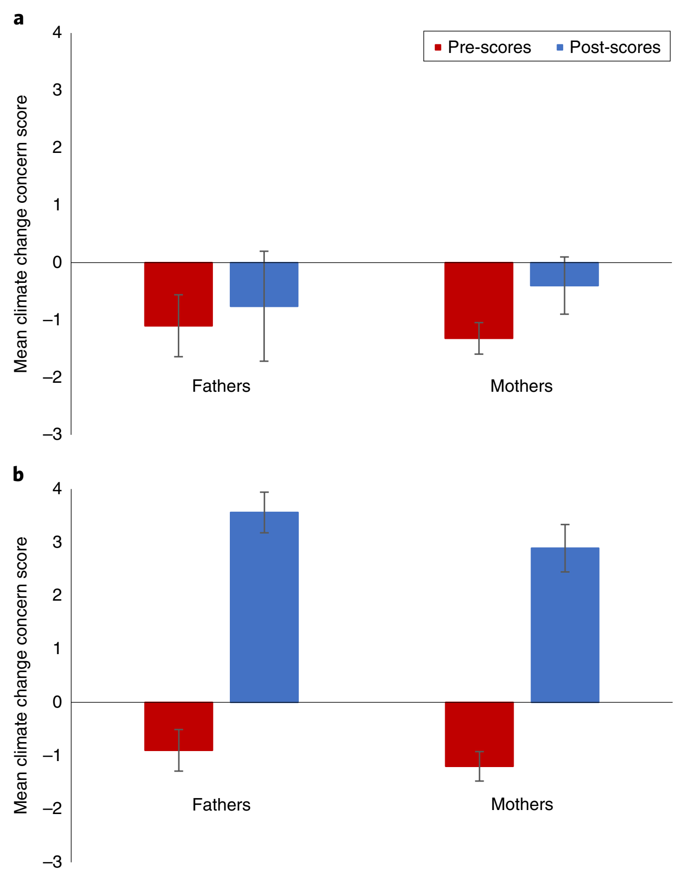

Fig. 2 | Climate change concern for fathers and mothers. **a**,**b**, Mean climate change concern scores for fathers ($n=35$) and mothers ($n=58$) in the control group (**a**) and for fathers ($n=61$) and mothers ($n=138$) in the treatment group (**b**). Error bars show 95% confidence interval.

decades despite climate communication efforts and are likely to have resulted in little to no action[1], climate change education focusing on adolescents may prove essential for the adoption of mitigation behaviours.

Our results also suggest that climate change education designed specifically for IGL can successfully reach parents. The relationship between the curricular treatment and parents' increase in climate change concern was fully mediated by the children's increase in climate change concern. This mediation follows similar patterns in the literature, where an environmental education curriculum did not directly target parents, but still led to measurable changes in knowledge, attitudes and behaviours in parents (for example, in energy education[21] and flood education[22]). Curricula that successfully promoted IGL included hands-on approaches, a focus on local issues, field-based experiences and encouragement of parental participation[5]. Our curriculum included each of these characteristics (Supplementary Table 2). Specifically, the curriculum was modelled after Project WILD to include hands-on approaches and a robust field-based learning project (Supplementary Table 3), focused locally in North Carolina, and promoted conversation between students and parents through a student-led parent interview about weather change. As framing climate change in local contexts leads to increased climate change acceptance among sceptical audiences[12,14], local examples in the curriculum may have boosted learning among children and parents alike, including those sceptical of climate change. The field-based service-learning portion of the curriculum is likely to have supported the sense that climate change impacts local areas[23] as well as promoting engagement among children[23]. Our findings show increased family discussion around climate change was a key factor in predicting changes in parents' concern levels (Table 2; $P=0.048$; Cohen's $f^2=0.357$), suggesting that the adolescent-conducted parent interview embedded in the curricula helped foster the child-to-parent IGL observed here.

The successful communication of climate concern from children to their parents documented in this study may reflect the robustness of the parent–child relationship to socio-ideological threats typically associated with climate change perceptions among adults. Parents who identified as male or conservative more than doubled their concern levels between pre- and post-tests—a larger increase than their female and liberal counterparts. This is surprising, as our own pre-test results and decades of research suggest that conservatives and men are the least concerned about climate change and are most resistant to interventions designed to promote concern[13]. However, high levels of parental trust in their children often leads to parents being willing to listen to or accept their child's views on complex topics[24]. IGL research reflects this pattern, showing for instance, that children influence their parents' knowledge and attitudes about sexual orientation[18]. Child-to-parent IGL of climate change information has been anecdotally documented in the popular press, with a conservative former US congressman switching his views on climate change due to his son's influence[25]. Our study provides empirical evidence of child-to-parent IGL associated with climate change concern, especially among those expected to be most resistant. Thus, children may provide a communication pathway that is resilient to longstanding socio-ideological barriers to learning about, caring about and ultimately acting to address climate change.

Daughters seem to be particularly effective at building climate change concern (more so than sons), perhaps because girls were

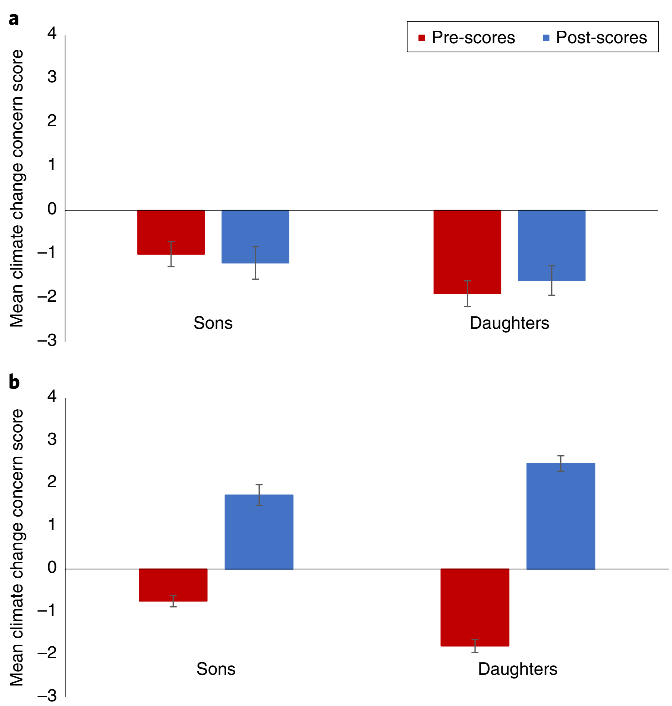

Fig. 3 | Climate change concern for parents of sons versus daughters. **a**,**b**, Mean climate change concern scores for parents with sons ($n=41$) or daughters ($n=52$) in the control group (**a**) and for parents with sons ($n=100$) or daughters ($n=99$) in the treatment group (**b**). Error bars show 95% confidence interval.

more concerned than boys post-intervention, or are better at communicating information during adolescence than boys[26]. Future research on IGL in the climate context should focus on testing these mechanisms to explain gender differences in communication outcomes. The tendency for parents' pre-test concern levels to be lower when surveys came from daughters than when they came from sons, as well as post-test concern levels in the control group, is troubling. Although not tested specifically in this study, there may be multiple explanations for this, including parents' tendency to talk less with daughters than sons about science[27]. Sons delivering the survey may trigger parents to think more about the topic as they associate science more with boys than with girls. Although determining the mechanisms behind daughters being more effective at eliciting parental climate change concern is a future research need, empowering girls to communicate about climate change with their parents may serve the dual purpose of working against typical gender roles that exclude girls from science and being particularly effective at building climate change concern among parents.

Mitigating the projected impacts of climate change requires increased climate concern and widespread collective action, and our results suggest that children can have a role in creating change now and in the future. Although our study confirms national survey findings[8] of incremental increases in climate change concerns over time, strategies are needed to accelerate this process. The compulsory nature of primary and secondary education in the United States and similar systems elsewhere represent an opportunity for curricula to increase the reach of climate change communication. Generalization from this experiment is likely to be strongest in other coastal areas that are vulnerable to the impacts of climate change, including sea-level rise and increased storm intensity and frequency. Future research should examine the efficacy of IGL for creating climate change concern in contexts where climate change presents less visible impacts, such as droughts in inland areas.

Future research would also benefit from collecting information about variables increasingly associated with climate change concern in children (for example, hope[17]), and including additional variables measuring the strength of relationships between parents and children (for example, trust). In addition to preparing children to address the climate challenges they will face, child-to-parent IGL provides children with means to promote the climate change concern needed to safeguard their future.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, statements of code and data availability and associated accession codes are available at https://doi.org/10.1038/s41558-019-0463-3.

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Author contributions

The ideas for this paper were conceived by D.F.L., K.T.S. and M.N.P. Data analysis was performed by D.F.L., K.T.S. and M.N.P. All authors contributed to the writing and editing of the paper.

Additional information

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Methods

Ethics statement. Data collection procedures were approved by North Carolina State University's Institutional Review Board (Protocol #7793). Informed consent was received directly from each adult participant before their participation in the research. Parental consent was received from each child's parent before child participation in the research.

Curriculum design. We designed the curriculum to maximize the chance of child-to-parent intergenerational transfer[28]. The curriculum developed for this project leveraged a previously tested curriculum[17], 'Weather, Wildlife, Climate and Change', which included four separate activities, modelled after Project WILD, an internationally distributed, wildlife-based, environmental education curriculum (see https://research.cnr.ncsu.edu/sites/wwcc/). The curriculum aligns with both North Carolina science standards (http://www.dpi.state.nc.us/curriculum/science/scos/) and Next Generation Science Standards[4]. The original curriculum was created through an iterative process with the State Climate Office of North Carolina (SCONC), the North Carolina Wildlife Resources Commission (NCWRC), North Carolina State University (NCSU) faculty and K–12 middle school classroom teachers. This process of expert elicitation was used to ensure that the climate change information was not only factually accurate, but also useable for science teachers. The curriculum focused on species local to both North Carolina and the southeastern United States (Supplementary Table 1), as individuals tend to engage with climate change more readily when it is framed in local contexts[5].The original activities focused on the difference between weather and climate, how climate and weather relate to wildlife habitat, how wildlife managers can make use of adaptive management to deal with climate change, and how individual actions can impact the effect of climate change on wildlife[17]. We added three components: engagement with parents through an interview conducted by students, a field-based service-learning project in conjunction with a community partner, and a reflective blog post (Supplementary Tables 1 and 3).

Sampling. We chose middle school children as the target age group for this study because early adolescence represents a developmental stage in which children are capable of understanding complex topics, such as climate change[19], and are still in the process of forming their own opinions on controversial subjects[20]. We chose to focus on the coastal counties of North Carolina, as this area is disproportionately vulnerable to climate change and its impacts, including sea-level rise and saltwater intrusion[29]. We used a hierarchical-sampling design[30], first creating a sample frame of all middle school science teachers (grades 6–8) in the North Carolina coastal counties, and randomly selecting 100 to invite to participate via email. Of the 100 invited teachers, 43 responded as interested (43% compliance) and 26 committed to the entire study (46.5% compliance). We randomly assigned teachers to treatment and control groups ($n=13$ control teachers, 13 treatment teachers). Although bias was possible in association with teachers knowing whether or not they were in a treatment or control group[31], any potential bias should be moderated by teachers not having direct contact with parents during the study. Over the course of the project, five teachers chose to withdraw from the study, citing lost instructional time due to impacts from Hurricane Matthew in October 2016, leaving 21 participating teachers ($n=9$ treatment teachers, $n=12$ control teachers), of whom 15 continued for the duration of the 2 yr study ($n=7$ control, 8 treatment). Because 15 teachers participated in both years, this yielded 23 distinct groups of students and parents ($n=11$ treatment, 12 control). Through the participating teachers, we gained access to our student sample, who were the students assigned to consenting teachers by school administrators for the school year. We invited parents to participate in an online and paper survey questionnaire children took home.

Children and parents were assigned to treatment or control groups based on association with the teachers. Our final treatment child sample consisted of 105 sixth-grade students, 153 seventh-grade students and 99 eighth-grade students. Children in the treatment sample ranged in age from 10 to 14 yr, and 52.0% self-identified as female and 55.9% as Caucasian. Our final control child sample consisted of 101 sixth-grade students, 121 seventh-grade students and 102 eighth-grade students. Children in the control sample ranged in age from 10 to 14 yr, and 51.6% identified as female and 54.0% as Caucasian. Our final parent sample consisted of 292 respondents ($n=199$ treatment parents, 93 control parents), from 238 individual families (54 households gave two parent responses), representing a 42.9% total response rate of possible households (that is, child and one or two parents). The total parent sample ranged from 29 to 84 yr of age, were 67.2% female, 79.1% Caucasian and 31.44% self-identified as conservative, 40.41% as moderate and 27.12% as liberal (Supplementary Table 4).

Teacher training. We trained all teachers in the curriculum following a delayed-treatment model[31] in summer 2016 (year 1 treatment teachers) and summer 2017 (year 1 control teachers), and used an in-person format allowing for discussion and reflection, which follows best practices for teacher professional development[32]. In year one, we asked the treatment teachers to integrate the lessons during the school year after pre-testing, and control teachers were asked to teach their regularly planned curriculum. All teachers integrated the curriculum lessons into their regular classrooms during year two (Supplementary Table 5 shows measures of fidelity of curriculum implementation).

Questionnaire development and deployment. To create our parent and child questionnaires, we used previously published scales that are validated for use with adolescents. Both child and adult climate change concern was measured using a scale developed from the 2011 nationwide climate change adolescent survey[33] and used in several subsequent studies[3,17] (Supplementary Tables 6 and 7). Level of climate change discussion in the family was measured through a single question, 'how often have you discussed climate change at home with your family?'. We also translated both the child and parent surveys into Spanish using Qualtrics translation services.

We collected child and parent responses twice each academic year, once at the beginning of the 2016–2017 school year, in October and November 2016, and again at the end of the school year, in May and June 2017. Responses were also collected at the same times of year during the 2017–2018 school year. All teachers were provided with a survey protocol and access to the student survey link through Qualtrics. On the same day that students were surveyed, we asked teachers to email all parents an online invitation letter with a URL and QR code that accessed the parent survey. Two weeks after the online survey letter was sent to parents, a paper survey packet was sent home with the students whose parents that had not yet responded. The paper survey packets contained a pre-addressed stamped envelope to facilitate easy and anonymous survey return to the researchers.

Data analysis. Before analysis, missing data were handled through multiple regression interpolation[31]; however, following best practice, if more than two variables were missing, that participant was excluded from the analysis[31]. We also tested for differences between our sample and non-respondents. First, we compared households with partial completion data (just pre- or post-test) with data used for analysis and detected no statistically significant difference in levels of climate change concern (student: $t(368)=0.417$, $P=0.677$; parent: $t(295)=1.641$, $P=0.102$), gender (student: $t(237)=-1.32$, $P=0.1874$; parent: $t(292)=-0.992$, $P=0.322$) or race (student: $t(236)=1.33$, $P=0.186$; parent: $t(291)=-1.160$, $P=0.247$). North Carolina voter registration records for our study area (33.1% Republican and 28.3% Democrat) aligned with political self-classification among parents in our study (31.44% conservative, 40.41% moderate and 27.12% liberal).

We used multiple linear regression analyses to model change in child climate change concern as a function pre-test scores of child climate change concern (to control for a ceiling effect[34]) and presence in a treatment group, controlling for student race, gender and treatment year. Random effects for teacher were included, but were not significant. We also used multiple linear regression analyses to model change in parent climate change concern as a function of pre-test scores of parent climate change concern, their child's presence in a treatment group and their child's change in climate change concern. Random effects were included for both family and teacher, but not significant. We also controlled for level of climate change discussion in the family, parent and child gender (male versus female), parent and child race/ethnicity (white versus people of colour), parent political ideology, school-level Title I status (a measure of socio-economic status[35]), school region development level (urban versus rural) and a random effect for teacher. We collapsed both child and parent ethnicity into dichotomous variables (0 for white, 1 for people of colour) owing to small sample size. We tested all interactions between student change in climate change concern and family dynamics variables including level of climate change discussion in the family, parent and child sex, parent and child race/ethnicity and parent political ideology. Only those interactions that were statistically significant were left in the model. Sobel–Goodman mediation tests were also run to test for the mediating effect of student change in climate change concern between treatments and parent change in climate change concern (complete mediation, 21% of the direct effect, $P<0.05$). Similarly, we excluded development status, Title I status and teacher random effects from the final models, as these factors were non-significant. Cohen's f statistics were calculated for each linear regression model following the formula $f=R^2/(1-R^2)$ and were categorized on the basis of accepted cut-off levels ($f\geq 0.02$, $f\geq 0.12$ and $f\geq 0.35$ for small, medium and large effect sizes, respectively). Effect size indicates numerically the size of the effect of the treatment, independent of the sample size[31]. The effects, shown in Tables 1 and 2, are considered medium effect sizes.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Data was collected using the NC State University Qualtrics Survey Software.
Data analysis	All data analysis was performed in STATA 14.2

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Behavioural & social sciences study design

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Study description	This study uses a quantitative pre-post/ treatment-control experimental design to test impacts of a standards-aligned, climate change curriculum on climate change concern among adolescents, and subsequently, among their parents through intergenerational learning.
Research sample	There are two samples in this study, and both were representative of the populations they represent. One is our middle school student sample. It includes a treatment group of 105 sixth-grade students, 153 seventh-grade students, and 99 eighth-grade students. These students ranged in age from 10 to 14 years, and self-identified as 52.0% females and 55.9% Caucasian. There is also a control group comprised of 101 sixth-grade students, 121 seventh-grade students, and 102 eighth-grade students. These students ranged in age from 10 to 14 years, and self-identified as 51.6% female and 54.0% Caucasian. No differences were found between our sample and the North Carolina population of students in terms of gender or ethnicity. Our second sample consists of students' parents (defined as guardians, parents, grandparents, foster parents, etc.). Our final parent sample consisted of 292 respondents (n = 199 treatment parents, n = 93 control parents). These individuals range from 29 to 84 years old, were 67.2% female, and 79.1% Caucasian. We chose early adolescents for this study as they possess the cognitive ability to understand complex scientific topics like climate change but also are young enough that socio-ideological filters that help form perceptions of socio-scientific issues are not fully formed. The parents were associated with each individual student; we had no direct contact with the parents per IRB protocol.
Sampling strategy	We used a hierarchical sampling strategy, by first sampling teachers, and through the teachers, their students, and through the students, their parents. This method maintained anonymity for adolescent participants and their parents, per the approved IRB protocol. A sample frame was first created of all middle school science teachers in our study area. A random sample of 100 teachers were invited via email to participate in the two-year research project. Of those 100, 43 responded as interested (43% compliance), and 26 committed to the entire study (46.5% compliance). Of those 26 teachers, 13 were randomly assigned to both treatment and control groups. Over the course of the project, five teachers chose to withdraw from the study citing lost instructional time due to impacts from Hurricane Matthew in October 2016, resulting in 21 teachers (n = 9 treatment teachers, n = 12 control teachers). Over the course of the two years, we had an additional 6 drop out for various reasons, although we still had 23 groups of students over the two year study (n =11 treatment; n = 12 control). Multilevel analyses call for a minimum of 20 units; and as such, we needed at least 20 participating classrooms. Students were assigned to each teacher following normal administrative procedures. Finally, parents were those associated with each student.
Data collection	Per IRB protocol, researchers were never present during data collection, thus maintaining anonymity. Student survey data were collected through an online survey on Qualtrics Survey Software, distributed through students' teachers. Parent survey data was collected in two ways. First, a letter was sent home by teachers to parents, containing a link to an online survey on Qualtrics. Two weeks after letters were sent home, survey packets containing a paper version of the survey were sent home by teachers, to those parents who had not yet responded to the online version of the survey.
Timing	Data were collected over the course of two years, and data collection occurred for both treatment and control groups, simultaneously. Pre-test surveys were sent to students and parents from October to November 2016 and 2017. Post-test surveys were sent to students and parents from May to June, 2017 and 2018.
Data exclusions	Data were excluded from analysis if more than section variables were missing for a single individual.
Non-participation	Of the teachers who were trained, five chose to withdraw from the study due to lost instructional time from Hurricane Matthew in October 2016. Of our possible student sample we had a 74.3% response rate, and of our parent sample, a 42.9% response rate per individual household.
Randomization	Participants were randomly allocated into treatment and control groups.

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Methods

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☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging

Human research participants

Policy information about studies involving human research participants

Population characteristics	See above.
Recruitment	Teachers were invited to participate in the study via email invitation. Self-selection bias among teachers was avoided by randomly assigning teachers to treatment and control groups. Further, our study subjects, students and parents, were not self-selected. Students were those associated with each teacher, and randomly assigned to classrooms following normal administrative protocols. Parents were also not self-selected and were those associated with each student. As such, we believe our results are not impacted by the teacher's self-selection bias.
Ethics oversight	North Carolina State University Institutional Review Board.

Note that full information on the approval of the study protocol must also be provided in the manuscript.