
The Effect of Participating in Climate Change Education Programs on Youth Self-Efficacy and Related Outcomes: A Systematic Review

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Appendix – Tables S2 and S3

Table S2

Characteristics and findings of studies examining the effect of participating in climate change education programs on youth self-efficacy.

Study & Population Characteristics		Climate Change (CC) Education Program Characteristics		Study Results		
Study Characteristics	Population Characteristics	Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes
<p>Carman et al., 2021</p> <p>Study Design: Quasi-experimental: Non-randomised controlled trial</p> <p>Country: USA</p>	<p>N: 582</p> <p>Attrition: 27% (matched questionnaires for n=426)</p> <p>Females: 51%</p>	<p>Age: range 12-13yrs</p> <p>Description: students taught by 9 teachers at 3 schools, class size ranged from 28-33 students</p> <p>Program: CC education unit about how scientists use mathematical models to predict climate change's impacts on forests: "Climate Change and Michigan Forests" (n=363)</p> <p>Content: Two-week education unit (9 lessons and one field trip)</p> <ul style="list-style-type: none"> - Lesson 1: Get in touch with trees: presentation, activities, & discussion on why forest ecosystems are important to humans and the environment - Lesson 2: Connections to CC: watch CC videos - Lesson 3: Down to the core: theory and activities on how scientists measure tree growth & predict how temperature/rain effect tree growth - Lesson 4: Scientific modelling of tree growth: theory & activities, generate scatter plot - Lesson 5: Making sense of data: students share & discuss their scatter plots & interpret models in a future greenhouse gas emissions situation - Lesson 6: Climate and plant growth: theory & discussion on climatic factors influencing plant growth & climographs - Lesson 7: Regional impacts and predictions: Students discuss how climate change impacts weather, ecosystems, & human economic activity within five biomes. Students collect, interpret, & organize information to make a Regional Prediction and Explanation based on supporting evidence. 	<p>Students who received the regular science curriculum (no CC education) (n=219)</p>	<p>Tool: researcher-developed survey (3-items; 5-point Likert scale)</p> <p>External validation: no. CFA: factor loadings & reliabilities for the seven factors were satisfactory to high.</p> <p>Time point: Pre- and post- intervention 2-weeks apart</p>	<p>Behavioural self-efficacy (the belief that one can take action to address climate change): mean (score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=227): pre: 3.94 (SD: 0.84); post: 4.12 (SD: 0.87) - <i>control</i> (n=198): pre: 3.85 (SD: 0.87); post: 3.69 (SD: 0.96) - <i>p</i> for time/group: p<0.0001 (exact p NR), favouring intervention <p>Correlations:</p> <ul style="list-style-type: none"> - knowledge correlated with self-efficacy - interest in the program and perceived importance of climate change correlated with self-efficacy 	<p>Knowledge</p> <p>Topic knowledge about CC and forests: mean</p> <p>Researcher-developed survey (n items NR; multiple choice questions with 5 answer options; score range NR; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=229): pre: 9.37 (SD: 4.14); post: 14.22 (SD: 5.39) - <i>control</i> (n=198): pre: 9.29 (SD: 4.46); post: 9.21 (SD: 4.86) - <i>p</i> for time/group: p<0.0001 (exact p NR), favouring intervention <p>Climate-related affect</p> <p>Perceived topic importance: mean</p> <p>Researcher-developed survey (3-items; 5-point Likert scale; score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=225): pre: 3.90 (SD: 0.90); post: 4.09 (SD: 0.88) - <i>control</i> (n=199): pre: 3.77 (SD: 0.88); post: 3.65 (SD: 0.88) - <i>p</i> for time/group: p<0.0001 (exact p NR), favouring intervention <p>Perception of CC threat: mean</p> <p>Researcher-developed survey (7-items; 5-point Likert scale; score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=227): pre: 3.92 (SD: 0.80); post: 4.09 (SD: 0.78) - <i>control</i> (n=199): pre: 3.86 (SD: 0.83); post: 3.77 (SD: 0.92) - <i>p</i> for time/group: p<0.0001 (exact p NR), favouring intervention <p>Desire to learn more: mean</p> <p>Researcher-developed survey (5-items; 5-point Likert scale; score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=213): pre: 3.48 (SD: 0.93); post: 3.35 (SD: 0.94) - <i>control</i> (n=188): pre: 3.36 (SD: 0.82); post: 3.06 (SD: 0.90) - <i>p</i> for time/group: p<0.0005 (exact p NR), favouring intervention <p>CC career interest: mean</p> <p>Researcher-developed survey (6-items; 5-point Likert scale; score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=229): pre: 2.83 (SD: 0.95); post: 2.88 (SD: 1.06) - <i>control</i> (n=199): pre: 2.77 (SD: 0.97); post: 2.73 (SD: 1.01) - <i>p</i> for time/group: <i>p</i>>0.05 (exact p NR) <p>Topic interest: mean</p> <p>Researcher-developed survey (5-items; 5-point Likert scale; score range 1-5; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - <i>intervention</i> (n=227): pre: 3.46 (SD: 0.84); post: 3.40 (SD: 0.95)

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Study Characteristics	Population Characteristics		Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes
			<ul style="list-style-type: none"> - Lesson 8: Student actions: Students define climate change mitigation & adaptation and discuss examples of each. They work in groups to collect information on how climate change impacts biomes, & actions they can take to mitigate & adapt to climate change. - Lesson 9: Student conference: Students work in groups to collect information on how climate change impacts biomes, & organize their findings into an informational poster. They present their posters to the rest of the class & grade each others' work using a peer evaluation rubric. - 2-hour field trip: Students visit a local forest & learn about different data collection methods forest ecologists use. They take a tree core sample & collect other tree growth & forest ecology data. <p>Underlying theory: interest theory</p> <p>Personnel involved: Teachers who had received training delivered the unit; individual and group components</p> <p>Setting: in-school</p> <p>Voluntary or compulsory participation: compulsory, imbedded in usual science classes</p> <p>Duration: 2 weeks</p>				<p>- control (n=196): pre: 3.32 (SD: 0.74); post: 3.16 (SD: 0.83)</p> <p>- p for time/group: p>0.05 (exact p NR)</p>
Deisenrieder et al., 2020	<p>N: 187</p> <p>Attrition: 10% (N=169 analysed)</p>	<p>Age: range 11-16yrs</p> <p>Description: 7 schools from both rural and urban settings</p>	<p>Program: participatory CC education program: "k.i.d.Z.21-competent into the future" Two parallel cohorts: 1). Students who participated in a CC protest (n=53), and 2). students who did not participate in a protest (n=116) (combined results NR)</p> <p>Content: Five modules integrated into high school curricula using teacher-centred classical</p>	Pre-intervention data	<p>Tool: researcher-developed survey (1-item; 6-point Likert scale)</p> <p>External validation: no, prior internal validation only</p>	<p>Self-efficacy: mean (score range 1-6; higher scores indicate higher self-efficacy):</p> <p><i>Protest students:</i></p> <p>- pre: 3.02 (SD: 0.97); post: 3.60 (SD: 1.06); p=0.001</p>	<p>Knowledge</p> <p>Mean correct answers</p> <p>Researcher-developed survey (13-items; 6-point Likert scale; score range NR; higher scores indicate higher knowledge)</p> <p><i>Protest students:</i></p> <p>- pre: 3.22 (SD: 1.37); post: 4.04 (SD: 1.42); p<0.001</p> <p>- Cohen's r: 0.5 (large effect size)</p> <p><i>Other students:</i></p>

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<p>Quantitative component: Quasi-experimental: non-randomised non-controlled trial</p> <p>Country: Austria & Germany</p>	<p>Females: 61%</p>	<p>school lessons and in individual research projects:</p> <ol style="list-style-type: none"> 1. Kick-off workshop 2. Traditional school lessons 3. Individual/group project 4. Research week (out-of-school; engage with experts, individually work on and respond to self-defined research questions) 5. Synthesis day/evening <p>Underlying theory: a mix of moderate constructivist with inquiry-based learning approaches, traditional teaching styles, and trans-disciplinary approach</p> <p>Personnel involved: Learn from teachers and experts/stakeholders; students worked individually as well as collaboratively in groups</p> <p>Setting: in-school</p> <p>Voluntary or compulsory participation: compulsory</p> <p>Duration: 1 year (Sept 2018-July 2019)</p>		<p>Time point: Pre- and post-intervention</p>	<p>ES- Cohen's r: 0.4 (medium effect size)</p> <p><i>Other students:</i></p> <p>- pre: 3.54 (SD: 1.04); post: 3.79 (SD: 1.21); p=0.019</p> <p>- Cohen's r: 0.2 (small effect size)</p>	<p>- pre: 3.15 (SD: 1.35); post: 3.64 (SD: 1.66); p=0.005</p> <p>- Cohen's r: 0.3 (medium effect size)</p> <p>Climate-related affect</p> <p><u>Perceived personal concern:</u> mean</p> <p>Researcher-developed survey (8-items; 6-point Likert scale; score range NR; higher scores indicate higher concern)</p> <p><i>Protest students:</i></p> <p>- pre: 4.49 (SD: 0.92); post: 4.79 (SD: 0.70); p=0.009</p> <p>- Cohen's r: 0.4 (medium effect size)</p> <p><i>Other students:</i></p> <p>- pre: 4.50 (SD: 0.89); post: 4.61 (SD: 0.83); p=0.201</p> <p><u>Perceived responsibility of climate friendly behaviour:</u> mean</p> <p>Researcher-developed survey (6-items; 6-point Likert scale; score range NR; higher scores indicate higher responsibility)</p> <p><i>Protest students:</i></p> <p>- pre: 5.19 (SD: 0.65); post: 5.37 (SD: 0.61); p=0.079</p> <p><i>Other students:</i></p> <p>- pre: 4.78 (SD: 0.84); post: 4.84 (SD: 0.93); p=0.545</p> <p>Behaviour</p> <p><u>Climate friendly behaviours:</u> mean</p> <p>Researcher-developed survey (20-items; 6-point Likert scale; score range NR; higher scores indicate more climate friendly behaviours)</p> <p><i>Protest students:</i></p> <p>- pre: 3.60 (SD: 0.61); post: 4.20 (SD: 0.61); p<0.001</p> <p>- Cohen's r: 0.7 (large effect size)</p> <p><i>Other students:</i></p> <p>- pre: 3.41 (SD: 0.86); post: 3.77 (SD: 0.83); p<0.001</p> <p>- Cohen's r: 0.5 (large effect size)</p> <p>Locus of control</p> <p>Mean, researcher-developed survey (3-items; 6-point Likert scale; score range NR; higher scores indicate higher locus of control)</p> <p><i>Protest students:</i></p> <p>- pre: 4.92 (SD: 1.12); post: 5.33 (SD: 0.86); p=0.003</p> <p>- Cohen's r: 0.4 (medium effect size)</p> <p><i>Other students:</i></p> <p>- pre: 4.76 (SD: 1.06); post: 5.14 (SD: 0.89); p<0.001</p> <p>- Cohen's r: 0.3 (medium effect size)</p>

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<p>DeWaters et al., 2014</p> <p>Study Design: Quasi-experimental; non-randomised non-controlled trial</p> <p>Country: USA</p>	<p>N: 427 (200 high school; 227 middle school)</p> <p>Attrition: NR</p> <p>Females: high school 40%, middle school 51%</p>	<p>Age: NR</p> <p>Description: middle and high school students from the different schools</p>	<p>Program: In-school education program with project-based climate change instructional modules to increase climate science literacy</p> <p>Content: a combination of lectures and hands-on activities. <i>High school students:</i> 11 modules each with 1-8 45-minute periods: 1) arctic ice; 2) amphibian phenology; 3) designing an apple orchard for future climate; 4) Lake Champlain ice; 5) climate connections (human impact on earth); 6) advising climate change policy around the world; 7) greenhouse gas inventory for a vacation; 8) greenhouse gas inventory for food miles; 9) mitigating climate change; 10) greenhouse gas emissions for electricity production; 11) understanding the greenhouse gas effect. <i>Middle school students:</i> completed 5 modules only: 1, 5, 8, 10, 11</p> <p>Underlying theory: project- and inquiry-based learning modules; rigor and relevance framework used for developing the modules</p> <p>Personnel involved: delivered by teachers who received extensive training to deliver the program; students worked individually as well as collaboratively in groups</p> <p>Setting: in-school, embedded in science curriculum</p> <p>Voluntary or compulsory participation: Compulsory</p> <p>Duration: 1 year (2012)</p>	<p>Pre-intervention data</p>	<p>Tool: researcher-developed survey (5-items; 5-point Likert scale; Likert scale questions converted to %)</p> <p>Validated: internally</p> <p>Time point: Pre- and post-intervention</p>	<p>Climate-related self-efficacy: mean % of maximum attainable score (score range 0-100%; higher scores indicate higher self-efficacy): <i>Middle school:</i> - pre: 70 (SD NR); post: 72 (SD NR); $p=0.03$ <i>High school:</i> - pre: 70 (SD NR); post: 71 (SD NR); $p>0.05$ (exact p NR)</p>	<p>Knowledge Climate-related content knowledge: mean % of maximum attainable score; researcher-developed survey (14-items; 5-point Likert scale; Likert scale questions converted to %; score range 0-100%; higher scores indicate higher knowledge): <i>Middle school:</i> - pre: 50 (SD NR); post: 58 (SD NR); $p<0.001$ (exact p NR) <i>High school:</i> - pre: 53 (SD NR); post: 59 (SD NR); $p<0.001$ (exact p NR)</p> <p>Climate-related affect Mean % of maximum attainable score Researcher-developed survey (14-items; 5-point Likert scale; Likert scale questions converted to %; score range 0-100%; higher scores indicate higher knowledge): <i>Middle school:</i> - pre: 60 (SD NR); post: 63 (SD NR); $p<0.01$ (exact p NR) <i>High school:</i> - pre: 62 (SD NR); post: 65 (SD NR); $p<0.01$ (exact p NR)</p> <p>Behaviour Climate friendly behaviours: Mean % of maximum attainable score Researcher-developed survey (9-items; 5-point Likert scale; Likert scale questions converted to %; score range 0-100%; higher scores indicate higher knowledge): <i>Middle school:</i> - pre: 62 (SD NR); post: 62 (SD NR); $p>0.05$ (exact p NR) <i>High school:</i> - pre: 61 (SD NR); post: 63 (SD NR); $p>0.05$ (exact p NR)</p>
<p>Gorr, 2014</p> <p>Study Design:</p>	<p>N: 87</p> <p>Attrition: NR</p>	<p>Age: range 13-15yrs</p> <p>Description: teachers were asked to select 2</p>	<p>Program: - Group 1: "KLIMA X" exhibition visit plus 1 CC class 2-weeks after the visit (n=36)</p>	<p>No "KLIMA X" visit or CC class (n=24)</p>	<p>Tool: researcher-developed survey (N items NR)</p> <p>External validation: NR</p>	<p>CC mitigation self-efficacy: mean (score range NR; higher scores indicate higher self-efficacy):</p>	<p>Knowledge Researcher-developed survey (score range NR): - <i>group 1:</i> $p>0.05$ (data and actual p NR) - <i>group 2:</i> $p>0.05$ (data and actual p NR) - <i>control:</i> $p>0.05$ (data and actual p NR)</p>

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<p>Mixed methods. Quantitative component: Quasi-experimental: 3-arm non-randomised controlled trial</p> <p>Country: Finland</p>	<p>Females: NR</p> <p>very strong students, 2 average students, and 2 students with learning difficulties</p>	<ul style="list-style-type: none"> - Group 2: "KLIMA X" exhibition visit only (n=27) <p>Content: "KLIMA X" interactive exhibition:</p> <ul style="list-style-type: none"> - Replicates a scenario of what would happen if the polar ice caps melted (floor covered with water, melting ice block, thunder, and rain) - Educational material (historical meteorological instruments in show cases, an installation illustrating the multiple sources of climate gases, 3D models of future life on Earth, videos, text panels, and projections of the changing ice coverage of the north pole, video wall with examples of how communities are currently already adapting to CC) - CC class (Group 1 only): presentation by teachers, short film, and assignments <p>Underlying theory: NR</p> <p>Personnel involved: teachers and students, individual & group participation</p> <p>Setting: in-school</p> <p>Voluntary or compulsory participation: compulsory school activity</p> <p>Duration: NR</p>		<p>Time point: pre- and 6-weeks post</p>	<ul style="list-style-type: none"> - group 1 (CC class): pre: 2.50 (SD NR); post: 3.50 (SD NR), $p<0.05$ - group 2: pre: 2.81 (SD NR); post: 3.01 (SD NR), $p>0.05$ - control: pre: 2.95 (SD NR); post: 2.98 (SD NR), $p>0.05$ <p>- between groups p: $p<0.05$ for group 1 vs. control; $p>0.05$ for other between-group comparisons</p>	<p>Climate-related affect Emotional involvement: mean Researcher-developed survey (score range NR; higher scores indicate higher emotional involvement):</p> <ul style="list-style-type: none"> - group 1 (CC class): pre: 2.99 (SD NR); post: 2.95 (SD NR), $p>0.05$ - within-group (exact p NR) - group 2: pre: 2.87 (SD NR); post: 3.15 (SD NR), $p<0.05$ - control: pre: 2.85 (SD NR); post: 2.94 (SD NR), $p>0.05$ - between groups p: $p>0.05$ <p>Belief: mean Researcher-developed survey (score range NR; higher scores indicate higher belief):</p> <ul style="list-style-type: none"> - group 1 (CC class): pre: 2.92 (SD NR); post: 3.00 (SD NR), $p>0.05$ - group 2: pre: 3.11 (SD NR); post: 3.37 (SD NR), $p>0.05$ - control: pre: 2.46 (SD NR); post: 2.46 (SD NR), $p>0.05$ - between group p: $p<0.05$ for group 1 vs. control; $p<0.05$ for group 2 vs. control; $p>0.05$ for group 1 vs. group 2 <p>Personal relevance: mean Researcher-developed survey (score range NR; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - group 1 (CC class): pre: 3.00 (SD NR); post: 1.50 (SD NR), $p<0.05$ - group 2: pre: 1.89 (SD NR); post: 2.04 (SD NR), $p>0.05$ - control: pre: 2.04 (SD NR); post: 1.73 (SD NR), $p>0.05$ - between groups p: $p>0.05$ <p>Action intention: mean Researcher-developed survey (score range NR; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - group 1 (CC class): pre: 2.65 (SD NR); post: 2.41 (SD NR), $p<0.05$ - group 2: pre: 2.45 (SD NR); post: 2.47 (SD NR), $p>0.05$ - control: pre: 2.54 (SD NR); post: 2.19 (SD NR), $p>0.05$ - between groups p: $p>0.05$
<p>Johnson et al., 2009</p> <p>Study Design: Mixed methods. Quantitative component:</p>	<p>N: 100</p> <p>Attrition: 26% (n=74 analysed)</p> <p>Females: 50%</p>	<p>Age: mean 19yrs (range 16-24yrs)</p> <p>Description: youth leaders, members of an environmental or humanitarian organisation, representing 28 countries, chosen</p>	<p>Program: Jane Goodall's Global Youth Summit 6-day education program</p> <p>Content: 6 days of environmental and humanitarian education programming:</p> <ul style="list-style-type: none"> - included 3 main content areas: cultures in conflict, wildlife conservation, and poverty - actively engaged in workshops, service projects, action planning, and cross-cultural dialogues on ethnic conflict and 	<p>Pre-intervention data</p>	<p>Tool: CSSES (10-items; 1-10 point Likert scale)</p> <p>External validation: yes, valid & reliable tool</p> <p>Time point: two weeks pre- and on</p>	<p>Community service self-efficacy: mean (score range 1-10; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - pre: 6.45 (SD: 0.73); post: 9.47 (SD: 0.64); $p<0.001$ - Cohen's d: 4.31 (very large effect size) <p>Skills Leadership Measured by CASQ sub-scale (5-items; 5-point Likert scale; score range 1-5; higher scores indicate higher perceived abilities to lead and their effectiveness as a leader)</p> <ul style="list-style-type: none"> - pre: 4.23 (SD: 0.53); post: 4.15 (SD: 0.52); $p=0.897$

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<p>Quasi-experimental: non-randomised non-controlled trial</p> <p>Country: conducted in USA, represents participants from 28 countries</p>	<p>based on competitive application process</p>		<p>social justice tensions arising from the 3 content areas</p> <ul style="list-style-type: none"> - participated in social and recreational activities to foster relationships e.g., participation in Earth Day parade and visits to animal centres involved in conservation. <p>Underlying theory: NR</p> <p>Personnel involved: experts mentored youth, individual and group participation</p> <p>Setting: external to school (international for some)</p> <p>Voluntary or compulsory participation: voluntary</p> <p>Duration: 6 days</p>		<p>the final day of the summit</p>		
<p>Johnson et al., 2013</p> <p>Study Design: Mixed methods. Quantitative component: Quasi-experimental: non-randomised non-controlled trial</p> <p>Country: Uganda</p>	<p>N: 133</p> <p>Attrition: 37% (n=84 analysed)</p> <p>Females: 50%</p>	<p>Age: mean 20yrs (range 16-24yrs)</p> <p>Description: unmarried members of Wildlife Clubs of Uganda in secondary school (grades 9-13)</p>	<p>Program: youth development program designed to increase knowledge and capacity for leadership and action in response to climate change</p> <p>Content: three 2 or 3-day workshops held in national forests:</p> <ul style="list-style-type: none"> - Workshops 1 & 3: Paired with scientists to conduct field work (conducted biodiversity assessments); environmental games (focused on environmental challenges and solutions (e.g., drama, song, and dance), debates, & discussions); presentation on role of science in conservation initiatives; film showing of CC documentary followed by group activity making posters (posters made only in workshop 1) and discussing CC concerns raised by the film - Workshop 2: fieldwork; environmental games; presentation on role of science in conservation initiatives; traditional 	<p>Pre-intervention data</p>	<p>Tool: GSES (10-items; 4-point Likert scale)</p> <p>External validation: yes, valid & reliable tool</p> <p>Time point: pre- and post-workshops</p>	<p>Self-efficacy: mean (score range 1-4; higher scores indicate higher self-efficacy):</p> <ul style="list-style-type: none"> - pre: 2.120 (SD: 0.05); post: 2.248 (SD: 0.05); p<0.01 (exact p NR) - partial n2: 0.10 (medium effect size) 	<p>Skills</p> <p>Interpersonal and problem-solving skills: mean Measured by CASQ sub-scale (12-items; 5-point Likert scale; score range 1-5; higher scores indicate higher skills)</p> <ul style="list-style-type: none"> - pre: 4.079 (SD: 0.07); post: 4.175 (SD: 0.06); <i>p</i>>0.05 (exact p NR) <p>Climate-related affect</p> <p>Political awareness: mean Measured by CASQ sub-scale (6-items; 5-point Likert scale; score range 1-5; higher scores indicate higher awareness)</p> <ul style="list-style-type: none"> - pre: 3.457 (SD: 0.11); post: 3.714 (SD: 0.08); p<0.01 (exact p NR) - partial n2: 0.11 (medium effect size) <p>Civic action (plans to engage in future civic actions): mean Measured by CASQ sub-scale (8-items; 5-point Likert scale; score range 1-5; higher scores indicate higher action)</p> <ul style="list-style-type: none"> - pre: 4.534 (SD: 0.05); post: 4.522 (SD: 0.06); <i>p</i>>0.05 (exact p NR)

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Study Characteristics	Population Characteristics	Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes	
		<p>drumming/dancing performance; group discussion of environmental concerns & reflective writing</p> <p>Underlying theory: NR</p> <p>Personnel involved: scientists mentored youth, individual and group participation</p> <p>Setting: external to school (after-school/week-end)</p> <p>Voluntary or compulsory participation: voluntary</p> <p>Duration: NR</p>					
<p>Kolenaty et al., 2022</p> <p>Study Design: Mixed methods. Quantitative component: Quasi-experimental: non-randomised non-controlled trial</p> <p>Country: Czech Republic</p>	<p>N: 429</p> <p>Attrition: 71% (N=123 analysed)</p> <p>Females: 57%</p>	<p>Age: range 12-17 yrs - 12-13yrs: 23% - 14-15yrs: 44% - 16-17yrs: 33%</p> <p>Description: students from 47 schools in rural areas, small towns, and big cities</p>	<p>Program: "CO² League" CC education program</p> <p>Content: Frequency of sessions NR. 4 targeted climate literacy components:</p> <ol style="list-style-type: none"> CC system knowledge & CC concern: watching videos, reading texts, brainstorming activities, depicting CC through mind maps & art-based activities, sharing results with schoolmates (posters, videos, presenting in front of class, website creation) CC action and effectiveness knowledge (mitigation), self-efficacy, personal climate action: calculating and discussing personal/school carbon footprint, implementing students' ideas to decrease their carbon footprint, sharing results with schoolmates (posters, leaflets, presenting in front of class, team website) CC action and effectiveness knowledge (adaptation), self-efficacy, community climate action: creating an urban 'feeling map' of local areas threatened by 	Pre-intervention data	<p>Tool: researcher-developed survey (7-items; 5-point Likert scale)</p> <p>External validation: no</p> <p>Time point: pre- & post- intervention</p>	<p>CC mitigation self-efficacy: mean (score range NR; higher scores indicate higher self-efficacy): - pre: 3.48 (SD: 0.70); post: 3.61 (SD: 0.74); p<0.05 (exact <i>p</i> NR) - Cohen's d: 0.2 (small effect size)</p> <p>Correlations: - strong correlation between climate change concern and self-efficacy - increased knowledge correlated with increased climate change concern - system, effectiveness, and action knowledge correlated with self-efficacy - strong correlation between self-efficacy and willingness to act</p>	<p>Knowledge</p> <p>System knowledge: mean Researcher-developed survey (3-items; 5-point Likert scale; score range NR; higher scores indicate higher knowledge): - pre: 1.16 (SD: 0.63); post: 1.48 (SD: 0.65); p<0.001 (exact <i>p</i> NR) - Cohen's d: 0.5 (medium effect size)</p> <p>Action knowledge: mean Researcher-developed survey (2-items; 5-point Likert scale; score range NR; higher scores indicate higher knowledge): - pre: 0.70 (SD: 0.45); post: 0.87 (SD: 0.45); p<0.001 (exact <i>p</i> NR) - Cohen's d: 0.4 (small effect size)</p> <p>Effectiveness knowledge: mean Researcher-developed survey (10-items; 5-point Likert scale; score range NR; higher scores indicate higher knowledge): - pre: 6.54 (SD: 1.14); post: 6.98 (SD: 0.13); p<0.001 (exact <i>p</i> NR) - Cohen's d: 0.3 (small effect size)</p> <p>Knowledge (aggregate i.e., overall): mean Researcher-developed survey (15-items; 5-point Likert scale; score range NR; higher scores indicate higher knowledge): - pre: 8.40 (SD: 1.28); post: 9.32 (SD: 2.01); p<0.001 (exact <i>p</i> NR) - Cohen's d: 0.5 (medium effect size)</p> <p>Climate-related affect</p> <p>CC Concern: mean Researcher-developed survey (8-items; 5-point Likert scale; score range NR; higher scores indicate higher concern):</p>

Study & Population Characteristics		Climate Change (CC) Education Program Characteristics		Study Results			
Study Characteristics	Population Characteristics	Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes	
		<p>drought, heat waves and floods, preparing proposals for adaptation measures</p> <p>4. CC self-efficacy, CC hope and empowerment, community climate action: interacting with local and national stakeholders, presenting students' mitigation and adaptation proposals to municipality officers, writing to relevant government officials</p> <p>Underlying theory: moderate constructivist approach; project and inquiry-based methods</p> <p>Personnel involved: teams of 3-6 students & 1 teacher tutor</p> <p>Setting: afterschool program</p> <p>Voluntary or compulsory participation: voluntary, students volunteered participation</p> <p>Duration: 1 year (2020-2021)</p>			<p>i.e., increased concern about climate change (reinforced by increased knowledge) led to higher self-efficacy, which led to greater willingness to act</p> <p>No sex or age differences in self-efficacy</p>	<p>- pre: 4.00 (SD: 0.63); post: 4.13 (SD: 0.63); <i>p</i><0.05 (exact <i>p</i> NR)</p> <p>- Cohen's <i>d</i>: 0.3 (small effect size)</p> <p>Willingness to act: mean</p> <p>Researcher-developed survey (8-items; 5-point Likert scale; score range NR; higher scores indicate higher willingness):</p> <p>- pre: 3.69 (SD: 0.74); post: 3.78 (SD: 0.67); <i>p</i><0.05 (exact <i>p</i> NR)</p> <p>- Cohen's <i>d</i>: 0.2 (small effect size)</p>	
<p>Petersen et al., 2020</p> <p>Study Design: 2-arm randomised non-controlled trial</p> <p>Country: Denmark</p>	<p>N: 102</p> <p>Attrition: 0%</p> <p>Females: 65%</p>	<p>Age: mean 14 yrs (SD: 0.75). Range: 13-15 yrs</p> <p>Description: students from 1 school</p>	<p>Program: CC education workshop utilising an immersive virtual reality field trip, with training material provided before the virtual reality trip, and involving design of a research project (n=50)</p> <p>Content: 3hr workshop:</p> <ol style="list-style-type: none"> Plenary discussion on CC controversies Teacher-led lecture on theory for developing research projects Listened to narrated training material on CC theory Immersive virtual reality trip to Greenland ("This is climate change: Melting Ice"). A 360 degrees non-interactive video about the melting Greenland ice sheet. In groups, developed a research project to test hypotheses about CC causes 	<p>Same workshop, but listened to the narrated training material on CC theory integrated within the virtual reality experience (not beforehand) (n=52)</p>	<p>Tool: researcher-developed survey (6-items; 5-point Likert scale)</p> <p>External validation: no</p> <p>Time point: pre- and post-workshop</p>	<p>Self-efficacy: mean (score range 1-5; higher scores indicate higher self-efficacy):</p> <p>- <i>intervention (pre-training)</i>: pre: 3.30 (SD: 0.68); post: 4.00 (SD: 0.67)</p> <p>- <i>comparator</i>: pre: 3.10 (SD: 0.63); post: 4.03 (SD: 0.70)</p> <p>- <i>p</i> for time/interaction: <i>p</i><0.0005</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.125</p>	<p>Knowledge</p> <p>Declarative knowledge: mean</p> <p>Researcher-developed survey (11-items; multiple choice questions with 4 answer options; score range: 0-27; higher scores indicate higher knowledge)</p> <p>- <i>intervention (pre-training)</i>: pre: 14.52 (SD: 3.09); post: 16.64 (SD: 4.06)</p> <p>- <i>comparator</i>: pre: 14.27 (SD: 2.86); post: 16.52 (SD: 4.60)</p> <p>- <i>p</i> for time/interaction: <i>p</i><0.0005</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.831</p> <p>Climate-related affect</p> <p>Interest in CC theory: mean</p> <p>Researcher-developed survey (4-items; 5-point Likert scale; score range 1-5; higher scores indicate higher interest)</p> <p>- <i>intervention (pre-training)</i>: pre: 3.72 (SD: 0.82); post: 4.06 (SD: 0.87)</p> <p>- <i>comparator</i>: pre: 3.42 (SD: 0.92); post: 3.96 (SD: 0.96)</p> <p>- <i>p</i> for time/interaction: <i>p</i><0.0005</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.198</p>

Study & Population Characteristics		Climate Change (CC) Education Program Characteristics		Study Results		
Study Characteristics	Population Characteristics	Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes
		<p>6. Group presentation/discussion on research project to fictitious panel</p> <p>Underlying theory: inquiry-based learning; social cognitive career theory</p> <p>Personnel involved: individual and group participation, teacher-led activities</p> <p>Setting: in-school</p> <p>Voluntary or compulsory participation: compulsory, conducted as part of standard education</p> <p>Duration: one workshop only</p>				<p>Outcome expectations (perceived social possibilities associated with an environmental career): mean</p> <p>Researcher-developed survey (3-items; 5-point Likert scale; score range 1-5; higher scores indicate higher expectations)</p> <p>- <i>intervention (pre-training):</i> pre: 3.67 (SD: 0.75); post: 3.79 (SD: 0.79)</p> <p>- <i>comparator:</i> pre: 3.44 (SD: 0.81); post: 3.62 (SD: 0.84)</p> <p>- <i>p</i> for time/interaction: <i>p</i>=0.026</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.653</p> <p>Science, technology, engineering, and mathematics (STEM) intentions: mean</p> <p>Researcher-developed survey (4-items; 5-point Likert scale; score range 1-5; higher scores indicate higher intention)</p> <p>- <i>intervention (pre-training):</i> pre: 2.72 (SD: 0.90); post: 2.95 (SD: 0.90)</p> <p>- <i>comparator:</i> pre: 2.43 (SD: 0.83); post: 2.70 (SD: 1.01)</p> <p>- <i>p</i> for time/interaction: <i>p</i><0.0005</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.752</p> <p>Behaviour change intentions: mean</p> <p>Researcher-developed survey (3-items; 5-point Likert scale; score range 1-5; higher scores indicate higher change intention)</p> <p>- <i>intervention (pre-training):</i> pre: 3.70 (SD: 1.00); post: 3.81 (SD: 0.95)</p> <p>- <i>comparator:</i> pre: 3.63 (SD: 0.88); post: 3.81 (SD: 0.80)</p> <p>- <i>p</i> for time/interaction: <i>p</i>=0.013</p> <p>- <i>p</i> for interaction/condition: <i>p</i>=0.600</p>
<p>Schrot et al., 2021</p> <p>Study Design: Mixed methods. Quantitative component: Quasi-experimental: non-randomised</p>	<p>N: 271</p> <p>Attrition: 15%</p> <p>Females: 56%</p>	<p>Age: range 16-18 yrs</p> <p>Description: students from 4 schools</p>	<p>Program: "Generation F³ – Fit for Future" CC education program (designed/implemented individual CC adaption research projects) (n=173; 2 cohorts, n in each NR)</p> <p>Content: 7 100min workshops & 2 full day workshops (involved presentations, discussions/questions, & adaptation role plays):</p> <ol style="list-style-type: none"> 1. Introducing CC, impacts & adaptations (orientation & discussion) 2. Science and research principles (orientation & discussion) 3. Finding a research question relevant to their own region (questioning) 	<p>Students in standard curriculum education (no CC education program) (n=98)</p>	<p>Tool: researcher-developed survey (4-items; 6-point Likert scale)</p> <p>External validation: no</p> <p>Time point: pre- & post- intervention/ control</p>	<p>Perceived self-efficacy: mean (score range 1-6; higher scores indicate higher self-efficacy):</p> <p>2017/2018 Cohort:</p> <p>- <i>intervention:</i> pre: 4.0 (95% CI: 3.8-4.2); post: 4.0 (95% CI: 3.7-4.2)</p> <p>- <i>control:</i> pre: 3.9 (95% CI: 3.6-4.2); post: 4.1 (95% CI: 3.9-4.4)</p> <p>- within group <i>p</i>>0.05 (exact <i>p</i> NR; between-group <i>p</i> NR)</p> <p>2018/2019 Cohort:</p> <p>- <i>intervention:</i> pre: 4.1 (95% CI: 3.9-4.3); post: 4.3 (95% CI: 3.4-4.5)</p> <p>- <i>control:</i> pre: 4.4 (95% CI: 4.2-4.6); post: 4.6 (95% CI: 4.5-4.8)</p> <p>- within group <i>p</i>>0.05 (exact <i>p</i> NR; between-group <i>p</i> NR)</p> <p>Perceived probability of CC: mean</p> <p>Researcher-developed survey (3-items; 6-point Likert scale; score range 1-6; higher scores indicate higher probability):</p>

Study & Population Characteristics		Climate Change (CC) Education Program Characteristics		Study Results		
Study Characteristics	Population Characteristics	Intervention	Comparator	Self-efficacy Tool	Primary Outcome: Self-efficacy	Secondary Outcomes
con- trolled trial Country: Austria & Italy		<ol style="list-style-type: none"> 4. Adaption problems & reframing research questions (orientation, discussion & questioning) 5. Specifying the research question (questioning & hypothesis generation) 6. Research methods & data analysis (orientation & discussion) 7. Refining research approach and data analysis (orientation, discussion & questioning) 8. Collecting data and interpreting results (exploration, experimentation & data interpretation) 9. Preparing scientific posters (conclusion) 10. Presenting scientific posters at public event with high profile stakeholders (communication) <p>Underlying theory: moderate constructivist approach (learning processes started with students' individual conceptions of CC action and real-life adaptation problems were an essential part of the education design); inquiry-based learning</p> <p>Personnel involved: individual student research project, supported by 57 scientific and practical experts on CC adaption and teachers</p> <p>Setting: in-school</p> <p>Voluntary or compulsory participation: voluntary, students volunteered interest</p> <p>Duration: 1 year (2 cohorts: 2017-2018 & 2018-2019)</p>			<p><i>2018/2019 Cohort:</i></p> <ul style="list-style-type: none"> - <i>intervention:</i> pre: 4.2 (95% CI: 4.0-4.4); post: 4.1 (95% CI: 3.9-4.3) - <i>control:</i> pre: 4.2 (95% CI: 4.0-4.4); post: 4.2 (95% CI: 4.0-4.4) - within group $p > 0.05$ (exact p NR; between-group p NR) 	<p><i>2017/2018 Cohort:</i></p> <ul style="list-style-type: none"> - <i>intervention:</i> pre: 3.2 (95% CI: 2.9-3.4); post: 3.1 (95% CI: 2.8-3.3) - <i>control:</i> pre: 3.4 (95% CI: 3.1-3.7); post: 3.6 (95% CI: 3.3-3.9) - within group $p > 0.05$ (exact p NR; between-group p NR) <p><i>2018/2019 Cohort:</i></p> <ul style="list-style-type: none"> - <i>intervention:</i> pre: 3.4 (95% CI: 3.3-3.7); post: 3.5 (95% CI: 3.3-3.7) - <i>control:</i> pre: 3.4 (95% CI: 3.3-3.7); post: 3.6 (95% CI: 3.4-3.8) - within group $p > 0.05$ (exact p NR; between-group p NR) <p>Perceived severity of CC effects: mean Researcher-developed survey (3-items; 6-point Likert scale; score range 1-6; higher scores indicate higher severity):</p> <p><i>2017/2018 Cohort:</i></p> <ul style="list-style-type: none"> - <i>intervention:</i> pre: 5.1 (95% CI: 4.9-5.2); post: 5.0 (95% CI: 4.8-5.2) - <i>control:</i> pre: 5.0 (95% CI: 4.8-5.3); post: 5.0 (95% CI: 4.8-5.3) - within group $p > 0.05$ (exact p NR; between-group p NR) <p><i>2018/2019 Cohort:</i></p> <ul style="list-style-type: none"> - <i>intervention:</i> pre: 5.1 (95% CI: 4.9-5.2); post: 5.2 (95% CI: 4.8-5.2) - <i>control:</i> pre: 5.0 (95% CI: 4.8-5.1); post: 5.3 (95% CI: 5.2-5.5) - within group $p > 0.05$ (exact p NR; between-group p NR)

CASQ: civic attitudes and skills questionnaire; CC: climate change; CSSES: Community Service Self-Efficacy Scale; GSES: General Self-Efficacy Scale; NR: not reported; post: post-intervention; pre: pre-intervention; SD: standard deviation; yrs: years.

Table S3

Grading of Recommendations, Assessment, Development and Evaluation (GRADE) for each outcome examining the effect of participating in climate change education programs on youth self-efficacy.

Certainty assessment							Certainty
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	
Self-efficacy							
9	observational studies	serious ^a	not serious	not serious	not serious	none	⊕○○○ Very low
Locus of control							
1	observational studies	serious ^a	not serious	not serious	serious ^b	strong association ^e	⊕○○○ Very low
Perceived importance of/concern for climate change							
3	observational studies	serious ^a	not serious	not serious	not serious	none	⊕○○○ Very low
Political awareness							
1	observational studies	serious ^a	not serious	not serious	serious ^b	strong association ^e	⊕○○○ VERY LOW
Belief in climate change							
1	observational studies	serious ^a	not serious	not serious	very serious ^c	none	⊕○○○ VERY LOW
Perceived threat/severity of climate change							
2	observational studies	serious ^a	serious ^d	not serious	not serious	none	⊕○○○ VERY LOW
Personal relevance of climate change							
1	observational studies	serious ^a	not serious	not serious	very serious ^c	strong association ^e	⊕○○○ VERY LOW
Climate change interest							
2	observational studies	serious ^a	not serious	not serious	not serious	none	⊕○○○ VERY LOW
Intention to change							
4	observational studies	serious ^a	serious ^d	not serious	not serious	none	⊕○○○ VERY LOW
Knowledge							
6	observational studies	serious ^a	not serious	not serious	not serious	strong association ^e	⊕⊕○○ Low
Behaviour							

Certainty assessment							Certainty
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	
2	observational studies	serious ^a	serious ^d	not serious	serious ^c	none	

- a. Risk of bias found in most domains of all studies
- b. ≤ 400 participants
- c. ≤ 100 participants
- d. 50% of studies found significant positive effect, 50% of studies found no significant effect
- e. Medium effect size