Localizing Climate Change Education: Impacts on Student Knowledge and Agency in High School Science Classrooms

Snowden, J., Guy-Gaytán, C., Harris, E. & Mohan, L.

Abstract

This study examined the impact of localized climate change education units on high school students' environmental science agency. Using a quasi-experimental design, teachers implemented both business-as-usual (BAU) and localized climate change units across two years. The localized units incorporated locally relevant climate issues while maintaining a standardized core curriculum. Data was collected using assessments of climate change knowledge, science identity, roles and expertise in science, and foundations for change. Mixed-effects models revealed that students who experienced the localized units showed significant gains in climate change knowledge and foundations for change compared to the BAU condition. While positive trends were observed, effects on science identity and roles/expertise were not statistically significant. Analysis of pre-existing climate change attitudes indicated that students with higher initial awareness or concern demonstrated greater improvements in their readiness to engage with climate solutions. The study suggests that supporting teachers in adapting climate change units for local contexts can enhance student knowledge and agency, potentially offering a scalable and equitable approach to climate change education. This research contributes to understanding effective climate education strategies and introduces environmental science agency as a framework for evaluating climate change learning outcomes.

Subject/Problem

As the climate crisis escalates, educators face the urgent challenge of not only helping students understand climate change but also fostering agency to address this global crisis (Stevenson et al., 2017). While understanding climate science principles and consequences is essential, it is equally important for students to see themselves as actors and take action in response to this global crisis (Ojala, 2012; Monroe et al., 2019). Cultivating an identity as someone who can use science to inform action as well as a sense of agency—the capacity to make informed decisions and take meaningful action—is vital for preparing the next generation to become active participants in climate solutions (Stevenson & Peterson, 2016).

Existing approaches to climate change education have shown promise in supporting student knowledge, identity and agency. Participatory action research positions students to identify local issues and lead their own investigation through interactions with community members (Schusler & Krasny, 2010; Trott, 2019). Citizen science projects involve students in collecting and analyzing data, contributing to real scientific research which can foster a sense of ownership and connection to science (Author, 2017). Place-based education in which students explore local climate impacts makes climate change more tangible and relevant (Littrell, 2020).

These approaches all help students make personal connections with climate change in their own communities, which can lead to closer psychological connection and greater concern and mitigation behavior (Busch & Chavez, 2022). However, these approaches can also be resource-intensive, requiring significant time, materials, and expertise (Monroe et al., 2019). This makes them challenging to scale, leading to inequitable access to such experiences.

To address the challenges of scalability while maintaining the benefits of localized climate change education, we designed a novel high school climate change unit and professional learning (PL) program that supported teachers to adapt and localize part of the unit. Our unit included a standardized "base unit" (approximately 75% of the unit) focused on global causes of climate change and carbon drawdown strategies. Supported by PL, teachers designed their own local pathways (about 25% of the unit) which included a local climate change problem to anchor the unit, 1-4 lessons focused on this local issue, and a final culminating task to engage students in local solutions. This structure enabled locally relevant contextualized learning experiences while minimizing the amount of teachers' design work. We conducted a quasi-experiment, with teachers serving as their own control, in which teachers taught a Business as Usual (BAU) climate change unit in the first year and then implemented their localized climate change units (localized unit) in the second year.

Theoretical framework. To conceptualize student outcomes, we draw on environmental science agency (ESA), a framework used to understand student participation in citizen science (Author, 2017). ESA consists of three interconnected components. First, students understand environmental science content and practices, which is a crucial foundation from which students act. Second, students identify areas of personal expertise within environmental science. This helps students recognize their own strengths and see themselves as contributors to science and problem solving. Finally, students use environmental science as a foundation for action and change in their lives and communities. Students develop action-oriented mindsets, essential for addressing the climate crisis. Through the lens of ESA, we explore the following questions:

1. Does **knowledge of climate change** differ after high school students learn with a localized unit versus a business-as-usual unit?
2. Does **science identity** differ after high school students learn with a localized unit versus a business-as-usual climate change unit?

3. Does a **sense of roles and expertise in science** differ after high school students learn with a localized unit versus a business-as-usual climate change unit?
4. Does **foundation for change** differ after high school students learn with a localized unit versus a business-as-usual climate change unit?

Design/Procedure

Study design. We used a cohort-controlled quasi-experimental design where teachers served as their own control, teaching their usual climate change unit (BAU) in the first year and implementing a localized unit in the second year after professional development. This design was chosen to allow for direct comparison of the two approaches while controlling for teacher-specific factors while integrating professional learning into the study. By having teachers implement both BAU and localized units, we could isolate the effects of the intervention while accounting for individual teaching styles and contexts.

Data collection. To address our research questions, we developed three assessment instruments. For RQ1, we created a three-dimensional transfer task to assess climate change knowledge, consisting of 20 multiple-choice and 4 open-response questions, based on the protocol by Harris et al. (2016). For RQ2, we designed a novel science identity measure with 13 Likert-scale items: 10 core items for all students, plus 3 randomly assigned from 6 additional items, evaluating students' science identity, motivation, and contribution in class. Lastly, for RQ3, we developed an instrument to measure students' sense of roles and expertise in science, comprising 29 Likert-scale items: 17 core items for all students, plus 12 randomly assigned from 24 additional items, assessing students' enjoyment of various classroom role-related activities across two hypothetical science-based scenarios.

To measure foundation for change (RQ4), we used the Transformative Experience Questionnaire, or TEQ (Littrell et al., 2022), which was adapted for climate change. The TEQ evaluates how students' learning extends beyond the classroom and captures their ability to apply learned concepts in external contexts, perceptual changes on climate change topics, and the value they perceive in new learning opportunities. The instrument consists of nine items on the pretest and fifteen on the posttest. To control for students' current disposition towards climate change we utilized the Six Americas Super Short Survey, or SASSY (Chryst et al., 2018). The SASSY categorizes respondents in one of six audience groups based on their perception and response to global warming using only four questions. The groups are: Alarmed, Concerned, Cautious, Disengaged, Doubtful and Dismissive.

Data analysis. We employed Rasch modeling techniques using Winsteps (Linacre, 2023) to estimate item and person measures. Specifically, we used a partial credit Rasch model (Masters, 1982) for the knowledge assessment, which contains items scored as correct or incorrect. For the three other measures consisting of polytomous items, we applied the Rasch Rating Scale Model (Andrich, 1978). Item and person measures are reported in logits, with zero representing the average item difficulty. Eight measures were calculated for each person using the pre and post-test data from each instrument.

We used Stata 15 (StataCorp, 2017) to estimate two-level random-intercept models (students nested within classrooms) to investigate the impact of individual and class level factors on each of our research questions'. Our model specification is as follows: Rasch person measures were used as the dependent variable, $Post\_Measure_{ij}$. β_1 to β_{10} are the coefficients for the continuous independent variables, the mean classroom measure ($class\_mean\_measure_j$) and the student's deviance from the classroom mean ($class\_dev\_measure_{ij}$) for the three other measures, students' categorization from the SASSY at pre-test ($SASSY\_Cat_{ij}$), and the chronological order of each classroom in a teacher's schedule (*PeriodOrder*$_j$). β_{11} to β_{16} are the coefficients for the categorical variables, each with their own set of dummy variables, free or reduced lunch status (FRL_{ij}), comfort reading and writing in English ($English_{ij}$), race ($Race_{ij}$), gender ($Gender_{ij}$), and grade ($Grade_{ij}$). β_{16} represents a set of coefficients for teacher fixed effects (TID_j), implemented as a categorical variable to account for teacher-specific influences. The final coefficient, β_{17}, corresponds to the treatment group indicator ($Treatment_j$). The term u_j denotes a random effect for each class, and ε_{ij} represents the error term for each student in each class. The standard errors are estimated at the classroom level. The data used in this study were collected during the cohort-controlled quasi-experimental trial of the project. A total of 2,062 students in 143 classrooms of 25 teachers spread across the United States participated in the study.

Findings and Analyses

SASSY. Analysis of the Six Americas Super Short Survey (SASSY) results at pretest revealed that the majority of participants held higher belief in climate change and were more concerned and motivated. The largest group was "Concerned" (39.34%), followed by "Alarmed" (27.36%) and "Cautious" (23.11%). These three categories collectively represented 89.81% of the sample. Smaller proportions were found in the "Doubtful" (6.54%), "Disengaged" (1.95%), and "Dismissive" (1.7%) categories.

Rasch. An analysis of the psychometric properties for each outcome measure is summarized in Table 1. The assessment tools were evaluated using criteria proposed by Boone, Staver, & Yale (2014), which suggest that good model fit is indicated by separation indices exceeding 2, reliabilities above .70, and low standard errors. All four instruments demonstrated robust psychometric characteristics based on these standards. The Knowledge assessment showed satisfactory reliability (0.78) and nearly met the separation threshold (1.88). The other three measures, Roles & Expertise, Science Identity, and Foundations for Change, exhibited exceptional reliability (0.92, 0.89, and 0.94 respectively) and separation (3.33, 2.89, and 3.94 respectively). Internal consistency was high across all measures, with Cronbach's alpha values ranging from 0.77 to 0.98. The instruments accounted for between 47.0% and 71.1% of the data variance. Importantly, all measures were found to be unidimensional, lending support to the validity of the constructs under investigation.

Table 1.

Summary of Rasch person fit statistics for each outcome measure

Instrument	Person Rel (Sep)	Item Rel (Sep)	Cronbach's Alpha	Variance Explained	Unidimensional
Knowledge	0.78 (1.88)	1.00 (19.00)	0.77	48.7%	Yes
Roles & Expertise	0.92 (3.33)	0.98 (7.73)	0.95	47.0%	Yes
Science Identity	0.89 (2.89)	0.97 (5.99)	0.91	53.8%	Yes
Foundations for Change	0.94 (3.94)	0.99 (14.03)	0.98	71.1%	Yes

Mixed-Effects Models. We employed mixed-effects models to test for baseline equivalence between the comparison and treatment conditions, finding no significant differences for all four outcome measures. Analysis of the treatment effects across all models revealed consistently positive outcomes, as indicated by the positive treatment coefficients presented in Table 2. Notably, the Knowledge and Foundations for Change models demonstrated statistically significant positive impacts of the treatment (both $p < .001$). In contrast, the models for Roles & Expertise and Science Identity, while positive, did not reach statistical significance ($p > .05$). The Knowledge model revealed a treatment coefficient of 0.257, suggesting that, when controlling for other variables, students exposed to the localized climate change curriculum outperformed students in the business-as-usual group by an average of 0.257 logits on the knowledge assessment. A comparable effect was observed in the Foundations for Change model, where the treatment coefficient of 0.246 indicated that, holding other factors constant, students in the treatment group scored an average of 0.246 logits higher than those in the control group.

Table 2.
Comparison of two-level random intercept models

Dependent Variable	Coefficient	p value	Constant
Knowledge	0.257	< 0.001	0.161
Roles & Expertise	0.092	0.096	0.092
Science Identity	0.077	0.267	-0.104
Found. for Change	0.246	< 0.001	-1.186

Table 3.
SASSY effects

Category	Coefficient	p value
Doubtful	0.2710	0.284
Disengaged	0.9015	0.003
Cautious	0.4904	0.037
Concerned	0.7555	0.001
Alarmed	1.1997	0.001

Analysis of the covariates in the Knowledge and Foundations for Change models identified several significant relationships among the class averages and deviations from class averages of the other measures. For the Knowledge model, the only significant covariate was the student's deviation from the class average Foundations for Change (TEQ) score, with an effect of 0.0429 logits ($p = 0.010$). In the Foundations for Change model only student's deviation from the class average Science Identity score was significant among the class averages and deviations, showing an effect of 0.202 logits ($p < 0.001$). Within the Foundations for Change model analysis of SASSY categories using "Dismissive" as the reference group, showed significant positive effects in four of the five categories as shown in Table 3.

Figures 1 and 2 illustrate these findings over time. Figure 1 displays the estimated average student knowledge scores while Figure 2 displays the estimated average foundations for change scores. While our initial baseline tests showed no significant differences, Figure 2 reveals that the treatment group has lower foundations for change scores at pretest than the control group due to the inclusion of additional control variables in our more comprehensive mixed-effects model that accounted for various student and classroom characteristics.

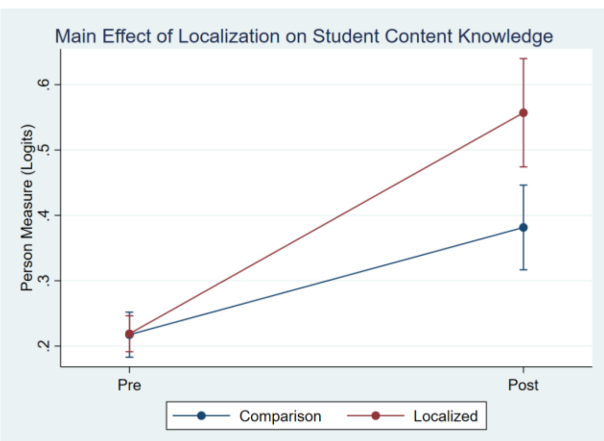

Figure 1. *Student Content Knowledge*

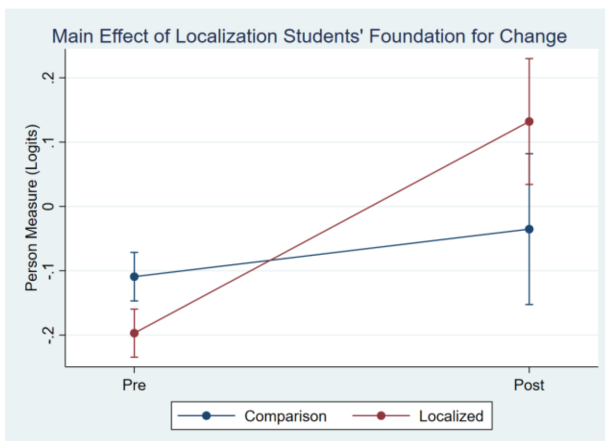

Figure 2. *Student Foundations for Change*

Contribution and General Interest to NARST

This study's findings contribute to the growing body of research on effective climate change education approaches, demonstrating that localized climate change units can enhance both students' knowledge and their foundation for change, addressing two crucial aspects of environmental science agency. The increase in climate change knowledge aligns with previous research on contextualized learning experiences where quasi-experimental studies in different contexts demonstrated significant knowledge gains from climate education programs (Flora et al. 2014; Monroe et al., 2019). Beyond gains in content knowledge, our study uniquely contributes by demonstrating significant improvements in foundation for change for students who experienced localized units. Within the foundations for change mixed-effects model, the significant coefficient of students' science identity indicates a positive relationship between students' science identity and their readiness to apply their climate learning outside the classroom. This finding suggests that students who identify more strongly with science may be more inclined to see themselves as to leverage their climate learning for change in their lives. Furthermore, our analysis of the SASSY categories demonstrates how pre-existing attitudes towards climate change may influence students' willingness to extend their learning beyond the classroom as a foundation for change. The significant positive effects suggest that students who started their units with higher levels of climate change awareness or concern tend to show greater gains in their readiness to engage with climate solutions than those who started with lower levels of awareness or concern.

We consider our findings in light of limitations of the study. First the quasi-experimental design may introduce potential confounding factors due to the non-random assignment of treatment. The nature of the design may have recruited teachers already interested in climate change duction, potentially biasing the sample towards more motivated and engaged educators. This selection bias could influence the generalizability of our results to the broader population. Lastly, the self-reported nature of some of the measures, particularly those related to identity and agency, may be influenced by students' desire to provide socially acceptable answers. Future research could address these limitations through randomized controlled trials and broader sampling strategies.

Our findings suggest that supporting teachers to adapt climate change units designed for localization holds promise as a climate change education approach. The localized units led to gains in student knowledge and agency, similar to other participatory action research, citizen science, and place-based education approaches (Authors et al., 2017; Littrell, 2020; Trott, 2019). While teachers still need to invest time and energy in their design work, localizing part of a unit of instruction may prove to be less resource-intensive than other approaches with similar outcomes. This has the potential to be widely accessible for many teachers, not just teachers who would design their own completely localized units, creating more equitable opportunities for students to study climate change in the context of their own communities. Our study also introduces the use of ESA as a lens through which to understand student learning about climate change, which has previously been applied only in citizen and community science. This approach can inform future efforts to study climate change education programs.

References

Andrich, D. (1978). A rating formulation for ordered response categories. *Psychometrika*, *43*, 561-573.

Author, 2017

Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch analysis in the human sciences*. Netherlands: Springer.

Busch, K. C., & Ayala Chávez, R. (2022). Adolescent framings of climate change, psychological distancing, and implications for climate change concern and behavior. *Climatic Change*, *171*(3), 21.

Chryst, B., Marlon, J., Van Der Linden, S., Leiserowitz, A., Maibach, E., & Roser-Renouf, C. (2018). Global warming's "six Americas short survey": Audience segmentation of climate change views using a four question instrument. *Environmental Communication*, *12*(8), 1109-1122.

Flora, J. A., Saphir, M., Lappé, M., Roser-Renouf, C., Maibach, E. W., & Leiserowitz, A. A. (2014). Evaluation of a national high school entertainment education program: The Alliance for Climate Education. *Climatic Change*, *127*, 419-434.

Harris, C. J., Krajcik, J. S., Pellegrino, J. W., & McElhaney, K. W. (2016). Constructing assessment tasks that blend disciplinary core Ideas, crosscutting concepts, and science practices for classroom formative applications. *Menlo Park, CA: SRI International*.

Linacre, J. M. (2023). Winsteps® Rasch measurement computer program (Version 5.6.0). Portland, Oregon: Winsteps.com

Littrell, M. K., Tayne, K., Okochi, C., Leckey, E., Gold, A. U., & Lynds, S. (2020). Student perspectives on climate change through place-based filmmaking. *Environmental Education Research*, *26*(4), 594-610.

Littrell, M. K., Gold, A. U., Koskey, K. L., May, T. A., Leckey, E., & Okochi, C. (2022). Transformative experience in an informal science learning program about climate change. *Journal of Research in Science Teaching*, *59*(6), 1010-1034.

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2019). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research*, *25*(6), 791-812.

Ojala, M. (2012). Hope and climate change: The importance of hope for environmental engagement among young people. *Environmental education research*, *18*(5), 625-642.

Schusler, T. M., & Krasny, M. E. (2010). Environmental action as context for youth development. *The Journal of Environmental Education*, *41*(4), 208-223.

StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC.

Stevenson, K., & Peterson, N. (2015). Motivating action through fostering climate change hope and concern and avoiding despair among adolescents. *Sustainability*, *8*(1), 6.

Stevenson, K. T., Nils Peterson, M., & Bondell, H. D. (2018). Developing a model of climate change behavior among adolescents. *Climatic Change*, *151*, 589-603.

Trott, C. D. (2020). Children's constructive climate change engagement: Empowering awareness, agency, and action. *Environmental Education Research*, *26*(4), 532-554.