Integrating Social Science Research to Advance Sustainability Education

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Abstract

The development and evaluation of the instructional module, *Southeastern Forests and Climate Change*, provided a platform to conduct social science research that has the capacity to improve sustainability education and our ability to achieve target outcomes. In addition to conveying information about climate change and forest management to secondary science students, the module was designed to empower learners to take action and build skills in systems thinking. We applied Hope Theory in the design of the 14 activities and measured hope among high school students who participated in the evaluation of the activities. Activities helped learners understand how others are working on climate issues, how forest owners adapt management protocols, and how individuals can contribute to solutions—all of which help nurture hopefulness and efficacy. We also focused on developing systems thinking skills by providing opportunities for students to learn and practice common systems tools, such as causal loop diagrams. High school students (n = 924) from 24 schools in the southeastern United States completed pre-and post-activity surveys that assessed knowledge, hope, and systems thinking skills. Data suggest that there was a significant increase in hope concerning climate change, and a significant increase in systems thinking skills after some activities. Knowledge of forest management, carbon cycle, the role of forests in mitigating climate change, life cycle assessment, and

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product externalities also significantly increased. In this article, we describe the principles used to design the activities, the results, and the implications of this social science research.

Keywords
Climate change · Hope · Systems thinking skills · Curriculum development

1 Introduction

Schools are society's opportunity to allow younger generations to gain knowledge and skills to become active and responsible citizens. Many of the goals of environmental and sustainability education, such as building skills for action competence (Uzzell 1999) and facilitating the thinking for future scenarios for sustainability (Kagawa and Selby 2015), are lacking in today's classrooms. This may be because the teaching strategies that lead to these outcomes are not well known.

Much is written and debated about the most effective ways to create meaningful experiences that engage youth in building both appropriate mental models and sufficient efficacy to take actions (Bandura 1977; Corno and Mandinach 1983; Johnson-Laird 1983; Kaplan and Kaplan 2009; Norman 1983; Peterson et al. 1982; Schunk 1985). Some researchers have alerted educators to the importance of enhancing students' disposition to use their knowledge and skills, as having ability is not the same as being willing to use it (Facione et al. 1997). Closely aligned with disposition are self-efficacy, outcome expectancy, and hope. Without hope, would students bother to learn about the complex issues facing society? When these issues are global and distant, can students believe they can do anything to make a difference?

Climate change is a challenging topic for educators who intend to nurture hope among their students. Knowledge alone can foster a depressing outlook on the future, with climate models suggesting the following potential outcomes:

- Sea level rise of 0.5 meters (20 inches) will cause coastal flooding and affect 5 million to 200 million people worldwide (NRC 2012).
- Habitat change due to climate could threaten nearly half the bird species in the continental United States and Canada by the end of century (NAS 2015).
- Challenges to agriculture as the human population approaches 8 billion could bring significant loss to the world economy (IPCC 2007, 2013; NRC 2011a, b; U.S. Global Climate Research Program 2009).

Unlike place-based and small-scale problems that students can tackle with success in their curriculum, climate change does not lend itself as easily to student projects that build self-efficacy, hopefulness, and a sense that they have the skills to address this challenge. Yet, research has demonstrated that hope is an essential element of engaging people in solving problems caused by climate change (Ojala 2007, 2012).

Hope is characterized by an expectation that the future will be better than the present and that one has the power to make it so (e.g., Averill et al. 1990; Bruininks and Malle 2005; Farran et al. 1995; McGreer 2004; Pettit 2004; Stotland 1969). According to Hope Theory (Snyder 2000), hope is a thinking process in which people exhibit agency thinking (willpower) and pathways thinking (waypower). Agency thinking refers to the appraisal that one is capable of executing the means to attain certain goals, and pathways thinking refers to the appraisal that one is capable of generating those means. Lopez and his colleagues (2000) transformed the notion of hope by defining three important characteristics of high-hope individuals. These individuals can (1) clearly conceptualize the goals, (2) envision a major strategy to a desired goal and generate alternative pathways, and (3) perceive that he/she has the ability and is willing to employ these strategies in pursuit of the goals. A 3-year longitudinal study with college students in the United Kingdom suggests that hope uniquely predicts personal achievement above intelligence, personality, and previous academic achievement (Day et al. 2010). Therefore, education programs that seek to help students consider how to effectively address climate change should nurture hope as well as increase understanding about the issue.

However, understanding climate change and its causes and impacts is not a simple task. Students can better understand how climate, ecosystems, and human activities are related when they use a systems perspective to approach the issue. Systems thinking is a method to help students think through complex problems (Skaza et al. 2013). It can force students to think beyond the familiar linear, cause and effect relationships they have come to rely on and to start considering the multitude of relationships that contribute to society's wicked problems. To do this, teachers need instructional materials that enable them to cover more than system structure and function and that challenge their students to understand the variables within a particular system and how they are directly and indirectly related. The strong presence of systems within the Crosscutting Concepts of the Next Generation Science Standards suggests that science educators should teach students how to understand and interpret system behavior and models (NGSS 2013).

Previous studies have demonstrated that students often lack the ability to comprehend the complexity of the climate system and identify and visualize the impacts of invisible components of a system (Shepardson et al. 2014). However, systems thinking skills are essential if students are to successfully engage in and thoroughly understand sustainability issues (Sandri 2013). Students need to understand that some environmentally friendly behaviors (e.g., littering, recycling, saving water) will not have an impact on mitigating climate change (Bofferding and Kloser 2015). Students need a deeper understanding of the interrelationships to know which actions will improve the system. Purposeful education that not only teaches about a system, but also to think at a systems level is needed to create a citizenry that can understand and appreciate complexity.

This study explored the levels of knowledge, hope, and systems thinking among high school students with the following questions: (1) Can climate change education programs nurture hope and enhance systems thinking skills? (2) Does an increase in knowledge decrease hopefulness?

1.1 Building Hope Through Instructional Activities

Over the past 30 years, researchers and educational professionals have worked to cultivate self-efficacy (Bandura 1977) to make a difference in students' lives and academic performance (Snyder et al. 2002). Self-efficacy is "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situation" (Bandura 1995, p. 2) which is a very similar if not overlapping construct with hope. Educators can contribute to the development of self-efficacy beliefs by utilizing the following strategies (Bandura 1977), all of which should also increase hopefulness:

1. Performance accomplishments: The experience of mastery enhances students' perspectives on their abilities.
2. Vicarious experience: The observation of someone else perform a task or handle a situation can help students perform the same task by imitation.
3. Verbal persuasion: When students are encouraged by others to perform a task, they tend to believe that they are more capable of performing the task.
4. Physiological states: The ability to diminish or control anxiety may have positive impact on self-efficacy beliefs.

We applied these four strategies and Hope Theory in designing an instructional module, *Southeastern Forests and Climate Change*. This secondary environmental education module focuses on climate change impacts on southern forest ecosystems, forest impacts on climate, and the ways people can affect these relationships. The 14 activities introduce concepts, provide data, engage students in discussions, and provide examples of how people are researching or addressing the issue. The impetus and framework for this activity was grant funding from USDA/NIFA focusing on climate impacts to southern pine management (see Monroe et al. this volume). All activities and resources can be downloaded from the module website (http://sfrc.ufl.edu/extension/ee/climate/). The four strategies for hope and the emphasis on systems thinking were used throughout the module to provide students with the inspiration and skills to address complex environmental issues. To measure our successes in conveying hopefulness and systems thinking skills, we conducted a thorough evaluation process to improve the value of the module while also answering our research questions.

Recognizing the limitations of practical links between climate change and hope, we developed the following four principles to design the lessons for this module:

1. **Others Care**. One aspect of hopefulness is believing that others are concerned about the same problem, which can reduce anxiety and create opportunities for vicarious experiences. We used a simple strategy of asking students to read and discuss articles from researchers associated with the Southern Research Station of the US Forest Service who have explored various aspects of climate variability and change in forests. These articles describe the questions and observations that motivated the scientists, their initial findings, and the tools they are developing to learn more about the effects of change on the forest systems. Students discuss these findings and recognize that work is being done that will help define problems and suggest solutions. In addition, climate and forest scientists and their graduate students are featured in the online slide presentations and videos, introducing students to careers in science that can help solve important problems.
2. **Others Are Doing Things**. Not only are others concerned, but many are currently engaged in actions that help mitigate climate change and support adaptations to likely promote change. We conveyed this key element of hope through lessons in several ways. After an introduction to the carbon cycle, students realize the power of carbon sequestration and the role forest landowners can play in using forests to mitigate change. An exercise on heredity reveals that scientists are breeding trees from across the natural range of loblolly pine to create seedlings that might exhibit tolerance to future climates. An explanation of climate science is followed by an exercise to help students understand some of the reasons that people disagree about climate change. Students then participate in a role play as a committee of individuals with different opinions who are asked to generate and evaluate recommendations for actions the community could take to address climate change. The ensuing discussion results in an increased understanding of why people hold different perspectives and their underlying interests. And finally, we introduce the concept of life cycle assessment (LCA) to help students realize that people are measuring carbon dioxide emissions of various products to suggest alternatives that might be better for climate.
3. **Things I Can Do**. Teachers specifically requested that we include examples of things students can do to affect climate change (Monroe et al. 2013). Since the focus of the module is on forest ecosystems, we avoided examples of energy conservation. While some youth might inherit forest lands, that could not be an assumed opportunity for all. To make forests relevant for all students, we focused on the LCA link to show that consumers can consider the impact of their purchasing decisions on climate. One activity helps students understand that durable wood products continue to sequester carbon, and using these instead of carbon-emitting alternatives can contribute to a significant reduction in atmospheric carbon dioxide. A concluding activity suggests ways students can work together on a service project in their community to raise awareness of the roles that forests play in carbon sequestration or strategies to enhance local forests. These activities combine persuasion and mastery in opportunities that students select; the materials do not advocate specific behaviors.

4. **Seeing Connections**. Climate change information can be depressing due to the variety of ways, suspected and unknown, that the climate system might respond to an increase in atmospheric carbon dioxide. While the negative consequences garner headlines in the environmental community, we sought to build skills in seeing connections that suggest a resilient system might be able to cope with some degree of climate change. An ecosystem's ability to adapt suggests that things may be different but will not collapse; we will still have plants and animals in some combination. While carbon sequestration will not "solve" the problem of climate change, students learn how forest ecosystems are resilient and how they may adapt under different climate conditions, but will not disappear completely. Our activities stress systems thinking skills so that students can recognize connections within a complex system and understand how that complexity enables the system to respond to change. This strategy is an attempt to diminish anxiety about climate change impacts.

1.2 Enhancing Systems Thinking Skills

To expand on the idea of "Seeing Connections" to bolster hope, we emphasized the development of systems thinking skills to take learners beyond simply seeing connections to being able to understand these connections, predict impacts of different relationships in a system, and apply solutions (Senge and Sterman 1992). Systems thinking helps students recognize patterns and interrelationships and imagine the impacts of changes to one variable in a system at different temporal and spatial scales. For many years, ecologists and business managers have used systems thinking to understand complex systems and to make predictions of how changes in one variable might alter critical outputs. The Next Generation Science Standards explicitly list systems as a crosscutting theme and expect that students will gain systems thinking skills in order to create models, and articulate or predict change. The prevalence of linear thinking, better suited for simple or artificial systems, speaks to the importance of teaching systems thinking in a manner that will empower students to use these skills to understand complex and nuanced systems. It is an interesting paradox that systems are everywhere and may be considered commonplace (e.g., digestive system, solar system) but this familiarity cannot help learners understand important systems concepts that help explain how systems behave, such as feedback loops or delays.

We utilized the forest and climate systems as the context for which students could begin to practice using systems thinking skills and tools. Students created causal loop diagrams to explore the relationships (both direct and indirect) that exist in a forest system and used computer models to see how climate change could impact tree and bird species. Behavior-over-time graphs were also used to depict how systems or their variables changed over time. These tools help students visualize systems, and better understand the variables that make up the system and the relationships between those variables.

2 Methods

2.1 Research Plan

To answer the research questions and assess the effectiveness of the educational resources, we utilized the evaluation as an opportunity to collect data for both research and evaluation questions (for evaluation information, see Monroe et al. this volume). To test learning outcomes, we grouped the activities into four packages and asked teachers to select the package that best fit their course objectives. Three of the module activities were not used in the evaluation and research process, as one had not yet been developed and two were culminating activities that were not feasible for teachers to complete. We used pre-experimental design, also called one-group pretest-posttest design, to collect data. A benefit of this design is the inclusion of a pretest to determine baseline scores, which allows us to ascertain whether a change in learning has taken place. Elements of hope and systems thinking were represented in each package (Table 1). The study was not about testing each strategy separately because some of the strategies, such as seeing connections, were used in activities that span all packages. Using a control group was not feasible because comparable lessons were not available that could cover the same content without also conveying hope or teaching about systems.

2.2 Procedure

We sent an invitation through several email lists to recruit secondary teachers from the southeastern United States after approval from the Institutional Review Board at University of Florida. From the 123 applicants, 36 high school teachers were selected to represent regional and grade level diversity. We purposefully selected the teachers from the counties with and without working forests based on the data from the USDA Forest Service Timber Products Output Reports Website (2013) and US Census Bureau (2013). They agreed to conduct the four assigned activities for their selected package during their regular instruction, collect the parental consent forms, and involve their students in pre- and post-activity surveys. Instructions were provided by mail and were reinforced in teacher emails. We asked teachers to administer the student pre-survey and post-survey within a week of finishing the activities.

2.3 Instruments

Student pre- and post-activity surveys were developed, reviewed by 9 experts to ensure content accuracy, revised, and pilot tested with 89 high school students. The student pre- and post- activity surveys included (1) a 14-item climate change hope scale (Cronbach alpha is 0.84) (Li and Monroe 2017), (2) 4 items on systems

Table 1 Packages with Activities, Knowledge-based Concepts, Learning Outcome and Hope Strategies

Package	Activity Titles	Knowledge-based Concepts	Hope Strategies				Systems Thinking Tools		
			Seeing Connections	Others Care	Others Are Doing Things	Things I Can Do	Causal Loop Diagram	Computer Model	Behavior Over Time Graph
1	The Real Cost	– Life cycle assessment – Externalities – Role of forests in mitigating climate change	X	–	–	X	–	–	–
	Adventures in Life Cycle Assessment		X	–	–	X	–	–	–
	Life Cycle Assessment Debate		X	–	–	X	–	–	–
	The Carbon Puzzle		X	X	X		–	–	X
2	Clearing the Air	– Forest management – Climate change science – Role of forests in mitigating climate change	X	X	X	X	–	X	X
	The Changing Forests		–	X	X	–	–	–	–
	Atlas of Change		X	–	–	–	–	X	–
	Managing Forests for Change		X	X	X	–	X	–	–
3	Managing Forests for Change	– Forest management – Carbon cycle – Carbon sequestration Genetic diversity	X	X	X	–	X	–	–
	Mapping Seed Sources		–	X	X	–	–	–	–
	Carbon on the Move		X	–	–	–	–	–	–

(continued)

Table 1 (continued)

Package	Activity Titles	Knowledge-based Concepts	Hope Strategies				Systems Thinking Tools		
			Seeing Connections	Others Care	Others Are Doing Things	Things I Can Do	Causal Loop Diagram	Computer Model	Behavior Over Time Graph
	Counting Carbon		X	–	–	–	–	–	
4	Clearing the Air	– Forest management – Life cycle assessment – Externalities Role of forests in mitigating climate change	X	X	X	X	–	X	X
	Managing Forests for Change		X	X	X	–	X	–	–
	The Real Cost		X	–	–	X	–	–	–
	The Carbon Puzzle		X	X	X		–	–	X

thinking skills, (3) 7 items covering demographic information, and (4) a 48-item test of knowledge. Systems thinking was only measured in packages 3 and 4 because we were interested in keeping the surveys short for packages 1 and 2 that had more younger students to reduce tests mortality. To reduce the pre-test impact on the post-test, the knowledge tests contained parallel questions with similar, but not the same, wording and answer choices. The climate change hope scale was developed from Snyder's (2000) Will & Ways hope scale and Ojala's (2012) Hope Concerning Climate Change scale for Swedish youth. The questions on systems thinking skills were guided by Stave and Hopper's (2007) taxonomy of systems thinking skills. Multiple choice questions were used to measure students' ability to identify the variables of a given system, the relationship between variables in the system, and the ability to interpret a system diagram and apply it to a new situation.

3 Results

3.1 Participants

Twenty-four pilot testers completed the activities and returned student pre- and post-surveys. About half (44%) of the teachers used the activities in environmental science or advanced placement (AP) environmental science classes. About 26% used the activities in biology and AP biology classes. Approximately 15% used the activities in earth science classes. The remaining teachers (15%) used the activities in courses such as land resources, economics, ecology, and environmental issues and investigation. Students (n = 924) from 24 high schools completed the pre-and post-surveys and had signed parent consent forms. Students were equally divided by gender; about 57% were 11th and 12th graders and 43% were 9th and 10th graders. However, the packages differed by age because they were designed to supplement different high school courses. As a result, 40% of students participating in packages 1 and 2 were 11th and 12th graders, while packages 3 and 4 reached 66% of this age group. About 14% self-identified as Hispanic. The majority of students were white (70%), with the remainder representing five racial communities (American Native = 1%, Asian or Pacific Islander = 2%, African American = 12%, two or more races = 8%, other = 6%). Student respondents were from Florida (42%), Kentucky (17%), Virginia (17%), North Carolina (12%), Georgia (4%), Arkansas (4%), and Oklahoma (4%).

3.2 Student Learning Outcome

We used dependent t-tests to compare student pre- and post-tests in terms of knowledge gain, hope change, and skills building. Data suggest that there was a significant increase in knowledge of LCA, externalities, climate science, forest management, carbon cycle, and the role of forests in mitigating climate change in

Table 2 Dependent T-tests Results from Students' Pre- and Post-tests

Learning Outcome	Pre-test Mean (n)	Post-test Mean (n)	T (one-tailed) (df)
Knowledge			
Package 1: LCA and externalities	2.83 (114)	4.25 (114)	2.98 (113)***
Package 2: Climate science, modeling, and forests management	3.64 (84)	4.15 (84)	0.9 (83)
Package 3: Carbon cycle and the role of forests in mitigating climate change	4.97 (171)	6.98 (171)	4.48 (170)***
Package 4: Climate science, LCA, and the role of forests in mitigating climate change	5.41 (178)	6.14 (178)	2.04 (177)***
Hope			
Package 1	58.28 (188)	60.37 (188)	1.56 (187)**
Package 2	56.87 (239)	58.46 (239)	1.29 (238)*
Package 3	56.65 (227)	58.40 (227)	1.43 (226)*
Package 4	62.03 (231)	64.06 (231)	1.86 (230)**
Systems thinking skills			
Package 1	–	–	–
Package 2	–	–	–
Package 3	1.96 (182)	1.97 (182)	0.54 (181)
Package 4	2.21 (194)	2.40 (194)	1.07 (193)*

Note $*p < .05$; $**p < .01$; $***p < .001$

Package 1, Package 3, and Package 4. Hope concerning climate change significantly improved among all four packages. Systems thinking skills stayed relatively the same in package 3, and significantly increased among students who received the package 4 (Table 2).

3.3 Knowledge and Hope

Multiple linear regression analysis was used to determine whether or not learning about forests and climate change significantly affected change in hopefulness while controlling for gender and grade level. Adding background information as controlling variables helps the model make predictions that are more accurate. We ran multiple regression analysis for each package and used the different value between hope post-score and pre-score (Posthope-Prehope) as the dependent variable.

Independent variables were the different value between knowledge post-score and pre-score (PostK-PreK), gender (0 = female; 1 = male), and grade level (0 = 9th and 10th grade; 1 = 11th and 12th grade). The results of the regression indicated the change in knowledge was a significant predictor in affecting change in hopefulness in package 1 (B = 1.03, $p < 0.01$) and 4 (B = 0.98, $p < 0.001$) when controlling for gender and grade level. The model explained 11.9% of the variance in package 1 ($R^2 = 0.12$, $F(4, 105) = 3.42$, $p < 0.05$) and 10.2% of the variance in package 4 ($R^2 = 0.10$, $F(4, 169) = 4.70$, $p < 0.01$). This indicates that as the knowledge score increases by one unit in package 1, hope increases by 1.03 units. Knowledge in package 1 highlights the carbon dioxide emissions associated with different products and examines the relationship between consumer choices and environmental impacts. As the score in knowledge increases by one unit in package 4, hope increases by 0.98 units (Table 3). Knowledge in package 4 connects climate science with life cycle assessment and the role of forests in mitigating climate change. It also highlights connections between today's decision and tomorrow's impacts through systems thinking.

Table 3 Regression Coefficients from Multiple Linear Regression Analysis

Package		B	SE B	β	T
1	Constant	3.49	2.31	–	1.51
	PostK-PreK	1.03	0.34	0.29	3.06**
	Gender	−0.71	1.72	−0.04	−0.41
	Grade level	−2.64	2.10	−0.14	−1.23
2	Constant	0.76	5.80	–	0.13
	PostK-PreK	0.39	0.51	0.08	0.77
	Gender	−0.50	2.37	−0.02	−0.21
	Grade level	1.81	5.80	0.05	0.20
3	Constant	2.25	1.33	–	1.69
	PostK-PreK	0.24	0.25	0.07	0.94
	Gender	−1.06	1.47	−0.05	−0.72
	Grade level	1.90	1.72	0.09	1.10
4	Constant	4.93	2.21	–	2.23*
	PostK-PreK	0.98	0.26	0.28	3.82***
	Gender	0.78	1.22	0.05	0.64
	Grade level	−2.88	2.14	−0.10	−1.3

Note *p < .05; **p < .01; ***p < .001

4 Implications for Sustainability Education

One result from this study suggests that hope can be nurtured through sustainability education materials. We learned that the activities were effective in enabling teachers to engage students in learning the concepts and nurturing hope about climate change. Seeing connections, learning that others care and are doing things, and understanding what students can do effectively built students' hope through agency and pathways thinking in the context of mitigating and adapting to climate change. A high school student from Florida recognized that he was gaining ideas about others when he commented: "I loved it! This activity taught me a lot about different perspectives and viewpoints from other people and opened my eyes to new horizons!"

Students in package 4 increased their systems thinking abilities after practicing with casual loop diagrams, computer models, and behavior-over-time graphs. In the post-surveys, students demonstrated they were able to read and interpret new diagrams and answer questions about system dynamics. Often students have an innate ability to think in terms of systems, but these abilities are not usually encouraged or practiced throughout K-12 education. When teachers made a conscious effort to emphasize systems thinking tools and vocabulary, they were able to foster systems thinking skills in students. Ideally these skills should become routine thinking habits that students are able to apply to any system. The difference between students who participated in package 4 and students who participated in package 3 demonstrates that the development of systems thinking skills takes practice with different content and a variety of tools.

Another key finding that emerged from this research was that an increase in knowledge about climate change can be accompanied by an increase in hopefulness, and it is not on the function of gender and grade level. However, the association between knowledge and hope depends on the type of information that is provided. If the knowledge highlights connections between today's decision and tomorrow's impacts, especially through systems thinking as in package 4, it is more likely that the increase in knowledge will lead to the increase in hopefulness. In addition, if the lessons focus on what students can do to address the issue, as in packages 1 and 4, hope is more likely to be fostered. Another factor, perhaps, could influence the result is that more students in package 4 are from Advance Placement Environmental Science class in which their teachers might have experience in teaching systems thinking or were introduced system thinking before.

These results and our experiences working with educators significantly altered how we designed the systems thinking component of the module. We realized the importance of helping teachers draw attention to systems components and demonstrate systems thinking. Now, each activity includes a Systems Thinking Connection section to highlight the skills and tools in the activity and tips for how the teacher can reinforce them. We learned from the teacher surveys that systems thinking was new for educators who do not teach Advanced Placement Environmental Science classes, and they were seeking more assistance in strategies to present content at a systems level. We also included discussion questions in the activity descriptions designed to help students think about a topic from a systems perspective. A new activity introduced the behavior-over-time graph that examine amount of carbon in the atmosphere over time. In addition to the systems thinking components of the activities, we believed that teachers needed an opportunity to practice systems thinking skills with their students in other contexts. We developed nine supplemental exercises that allow students the opportunity to apply their newly developed skills to novel systems. One of these activities introduces students to another systems thinking tool, stock-and-flow diagrams. The nine exercises can be found on the module website and include activity sheets to practice diagrams and online tools for practice with models.

Limitations of this study provide insights for future research. Students were not randomly selected and teachers who pilot tested the program were volunteers who were interested in teaching about climate change and received a stipend, which constrains the ability to generalize these results to other populations. We did not test the design principles separately, since they were utilized repeatedly in many activities. An experimental study could be developed to test the effectiveness of a single principle. Longitudinal studies are needed to answer additional research questions such as, how long lasting are program effects on hope and systems thinking and would the effects influence students' willingness to participate in environmental problem-solving as an adult? Future research could look at whether or not the assumptions hold true for adult learners and other factors that we did not include in this study, such as environmental identity, perceptions about anthropogenic climate change, and perceived risks. The relationship between hope and systems thinking needs to be further tested. Future study could also look at how to teach teachers about systems thinking and evaluating whether the changes we made in the module help them teach and influence their efficacy in teaching systems thinking skills.

5 Conclusion

Effective climate change education should not only increase learners' understanding about the issue but also nurture a sense of hopefulness. Without hope, information might create a depressing and pessimistic outlook for the future. Sustainability educators can develop and nurture a sense of hopefulness by showing examples of people who are currently working to understand, mitigate and adapt to climate change, as well as the potential for others to join them. This can help learners broaden their hope pathways thinking. Opportunities at an appropriate scale can help learners explore, investigate issues, and resolve to build responsibility and hope agency thinking. Using systems thinking to make choices and understand consequences could help individuals identify a need, create a vision, and design an action plan, even if other people are responsible for implementing it.

The scale of climate change makes it difficult to empower learners to be skilled and hopeful, since it can be challenging to see the impact that small-scale actions have on a global problem. Yet that is exactly what all of us are capable of doing. Carefully using systems thinking to help teachers and students understand the connections and apply solutions to problems of similar scale should help students develop systems thinking skills and may help nurture hope.

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