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Connecting Community and Citizen Science to Stewardship Action Planning Through Scenarios Storytelling

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Community and citizen science on climate change-influenced topics offers a way for participants to actively engage in understanding the changes and documenting the impacts. As in broader climate change education, a focus on the negative impacts can often leave participants feeling a sense of powerlessness. In large scale projects where participation is primarily limited to data collection, it is often difficult for volunteers to see how the data can inform decision making that can help create a positive future. In this paper, we propose and test a method of linking community and citizen science engagement to thinking about and planning for the future through scenarios story development using the data collected by the volunteers. We used a youth focused wild berry monitoring program that spanned urban and rural Alaska to test this method across diverse age levels and learning settings. Using qualitative analysis of educator interviews and youth work samples, we found that using a scenario stories development mini-workshop allowed the youth to use their own data and the data from other sites to imagine the future and possible actions to sustain berry resources for their communities. This process allowed youth to exercise key cognitive skills for sustainability, including systems thinking, futures thinking, and strategic thinking. The analysis suggested that youth would benefit from further practicing the skill of envisioning oneself as an agent of change in the environment. Educators valued working with lead scientists on the project and the experience for youth to participate in the interdisciplinary program. They also identified the combination of the berry data collection, analysis and scenarios stories activities as a teaching practice that allowed the youth to situate their citizen science participation in a personal, local and cultural context. The majority of the youth groups pursued some level of stewardship action following the activity. The most common actions included collecting additional years of berry data, communicating results to a broader community, and joining other community and citizen science projects. A few groups actually pursued solutions illustrated in the scenario stories. The pairing of community and citizen science with scenario stories development provides a promising method to connect data to action for a sustainable and resilient future.

Keywords: action science, climate change learning, environmental education, futures thinking, resilience thinking, scenarios development, youth

INTRODUCTION

Community and citizen science on climate change-related topics offers a way for participants to actively engage in understanding the changes and documenting the impacts (Dickinson and Bonney, 2012; Pecl et al., 2019). Community and citizen science spans a spectrum of collaborations between public participants and professional scientists in conducting scientific research, from "contributory" program designs where public are involved only in data collection to "co-created" projects where scientists and community members collaborate on all or most phases of the research (Shirk et al., 2012; Bonney et al., 2014). In large scale contributory projects, where participation is primarily limited to data collection, it is often difficult for volunteers to see how the data can inform decision making that can help create a positive future. Further, in vast climate change-related contributory projects, the majority of participants feel powerless to act on such big, complex issues (Jordan et al., 2011).

This is not the case in smaller scale, co-created environmental projects, which tend to be created with the intent for action or self-advocacy and allow for more rapid and visible use of the data for decision making and policy changes (Danielson et al., 2010; McGreavy et al., 2016). Much research and program design innovation is still needed to create visible linkages between the data volunteers have collected in contributory programs and how the data can be used for the future beyond the scientific publications and program newsletters.

This is particularly true in youth-focused citizen and community science programs, where educators are seeking to help develop a sense of agency in their youth, but youth often aren't able to make the connections between the act of data collection and how it can contribute to the future (Ballard et al., 2017). Many studies show that children and youth in the current generation have pessimistic visions of the future in a changing climate (Hicks and Holden, 2007; Naval and Reparaz, 2008; Threadgold, 2012), and that the pessimism tends to increase with age as youth come to realize the complexity of the global climate change issue (Eckersley, 1999; Hicks and Holden, 2007). Late childhood and early adolescence are pivotal periods for the development of the hope and sense of agency that can either hinder or support the growth of their desire to seek knowledge and their competencies for sustainability action (Ojala, 2012). In this paper, we test a method of initial steps in scenarios stories development within a large youth-focused contributory citizen and community science program. The method is designed to link the youth's science process and data collection to a positive vision of the future and concrete local stewardship actions that they could plan and implement.

Determining a plan for the future is a challenging task in any context, and is a skill that must be practiced. Scenarios story development is a strategy that has risen in popularity within the climate change adaptation and planning field, and is a process of taking the information available, asking "what if?", and articulating stories to these possible futures that can directly inform planning, decision-making, and stewardship action (Mietzner and Reger, 2005; Millennium Ecosystem Assessment [MEA], 2005; Carpenter et al., 2006; Amer et al., 2013). The steps for scenarios planning involve: (1) reviewing current and past knowledge of the environmental issue, (2) defining a focal question and relevant time frame for the scenarios, (3) identifying forces and factors that have an effect on the focal question, (4) identifying the critical uncertainties, (5) developing the characteristics of multiple possible scenarios based on different actions pursued, and (6) determining the implications of the different actions taken in the different scenarios and prioritizing actions based on this assessment (O'Brien, 2004; Amer et al., 2013). The scenarios story development process can be greatly informed by citizen and community science data. For example, steps one through three can be informed by the data collected and step four can be pursued using citizen and community science methods to collect further data needed to address the uncertainties.

The practice of envisioning and planning for the future in youth environmental education has been studied with more frequency over the last 25 years. In one repeat study in the south of England conducted in 1994 and then again in 2004, Hicks and Holden (2007) asked 11 and 14 year olds about their hopes and fears for the future at a personal, local and global scale. The youth demonstrated concern and knowledge about present-day activities both damaging and improving future conditions. The study guagued the ability of futures-oriented teaching practices to enable students to imagine the future and to facilitate students' understanding that their actions were important and mattered in determining pathways to the future (Hicks and Holden, 2007). Other studies have more specifically documented the application of scenario stories in youth settings. Lloyd (2011) employs scenario story writing in two undergraduate courses in the geosciences. Lloyd writes, "Futures scenarios provide starting points for action that preserves what is good and changes that which is bad, evil, or unsustainable. They develop foresight, assist in deep and meaningful learning, promote behavioral change, are empowering (an aspect of well-being) and develop creativity" (Lloyd, 2011, 99). Scenario exercises were also applied in Chalaco, Peru with 11–13 year olds to consider the conservation and futures of Chalaco's resources, watershed and mountainous ecosystem by The Sustainable Development Mountain Ecosystem Programme (PDSEMP in Spanish). Interestingly, limitations were identified in these age group's perceptive ability to think 5–10 years into the future. PDSEMP, too, had to simplify the process in order to focus students' attention on the key takeaways from what thinking about the futures is intended to elicit (Velarde et al., 2007). This process has been used with youth to help bring youth voice to community planning in the Arctic Future Makers project (Cost and Lovecraft, 2020). Cost and Lovecraft (2020) found that high school-aged youth were adept at identifying key factors that impact their community's ecosystem (steps 1–3), but had a more difficult time imagining the future.

As demonstrated in these studies, futures thinking and scenarios development exercises are useful strategies to empower youth to think more strategically while relying on the best knowledge to date to better inform decision-making (Hicks and Holden, 2007; Velarde et al., 2007; Lloyd, 2011; Cost and Lovecraft, 2020). We sought to employ a brief sample of the scenarios story development process to see if we could draw a connection between the gathering data in a community and citizen science project and using it to inform imagining possible futures and laying a pathway to a desirable future. We also saw the combination of these two activities as a way for youth to practice the thinking skills necessary for navigating a rapidly changing environment (Spellman, 2015).

Both the social-ecological resilience and education for sustainability literatures agree on several thinking skills that are key to building the collective ability of communities to adapt to and shape change (reviewed in Wiek et al., 2011; Spellman et al., 2016). We refer to these skills as "resilience thinking skills," which we define as higher order cognitive skills that support problem solving in a social-ecological system context. The key resilience thinking skills include the ability to interpret and apply new scientific information to novel situations (Carpenter, 2002; Folke et al., 2003; Fazey et al., 2007), systems thinking (e.g., the ability to consider both social and ecological aspects of a problem and how they interact; Sterling, 2005; Meadows, 2008; Crawford and Jordan, 2013; Hmelo-Silver et al., 2017), futures thinking (e.g., the ability to think about future events or future desired ecological states and anticipate the consequences of present actions taken by humans; Ascher, 2009; Tschakert and Dietrich, 2010; Tidball and Krasny, 2011), and sense of human agency (e.g., the ability to understand the agency of humans within the ecosystem and imagine strategies to move toward a desired social-ecological state; Brundiers et al., 2010; Wiek et al., 2011; Ballard et al., 2017). In youth environmental and science education programs, the suite of these thinking skills could be addressed through the novel pairing of citizen science engagement and scenarios storytelling.

We see great potential for using scenarios story development in conjunction with youth-focused citizen and community science as a way to facilitate youth directly linking their data with hope for a positive future, practicing resilience thinking skills, envisioning a pathway for action, and imaging themselves as agents of environmental stewardship action (**Figure 1**). In this paper, we demonstrate this method across diverse youth groups involved in a wild-berry focused citizen and community science program. In our demonstration of this method, we explored the following questions:

- Does using scenarios storytelling allow youth to exercise resilience thinking skills?
- Does scenario storytelling allow youth to picture themselves as agents of change in the ecosystem?
- Does the extent to which the activity exercised these outcomes (resilience thinking skills demonstrated and youth picturing themselves as agents of change) vary by community setting and grade level?
- What value did the educators perceive in using scenarios storytelling to culminate the citizen and community science experience for their youth group?
- Did educators report that youth groups pursued stewardship actions after the activity? If so, what types of actions were pursued?

MATERIALS AND METHODS

Study Setting

We tested our method of pairing community and citizen science with scenarios storytelling with thirteen youth groups and a total of 170 youth who participated in the Winterberry Citizen Science program across Alaska (**Table 1**). Six youth groups from 5 rural (defined as communities with population <2,500; U.S. Census, 2010) predominantly Alaska Native villages and seven urban (population >2,500) youth groups from two towns tested the method across a variety of age groups and learning settings. The groups spanned formal and informal learning settings and three grade levels we categorized as primary grades (ages 5–9; five groups), intermediate (ages 9–12; four groups), and secondary (ages 13–18; four groups) (**Table 1**). Grade level categories were based on the groupings within the rural village schools and youth programs included in the study, which had multiage classrooms or youth groups due to small village populations within this study (range 83–1405 people; U.S. Census, 2010).

In the Winterberry Citizen Science program, youth groups and adult volunteers collaborated with University of Alaska ecologists to investigate the influence of the changing timing of the growing season on four native species with fleshy fruits (Alaska wild rose–*Rosa acicularis*, lowbush cranberry–*Vaccinium vitis-idaea*, highbush cranberry–*Viburnum edule*, and crowberry–*Empetrum nigrum*) commonly referred to as "berries" throughout the state. The species were selected because (1) they are important species for subsistence and recreational harvesting across Alaska, (2) they are widely distributed throughout the state, and (3) they retain a high proportion of fruit in the fall and winter. Each volunteer group marked and "adopted" twenty or more individual plants with a minimum of 100 berries and tracked the abundance and condition of the berries (ripe, rotten, damaged by frugivores, or dried) on each plant in fall and spring,

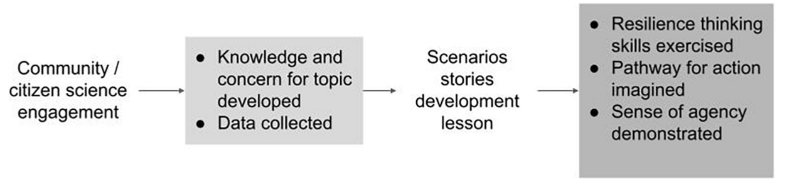

FIGURE 1 | Proposed theory of change model for youth concluding a climate change-related community and citizen science project with a scenarios development mini-workshop.

TABLE 1 | Resilience thinking rubric scores for youth work samples of scenario stories created with Winterberry Citizen science data and berry stewardship action brainstorming.

	No. groups	No. youth	Resilience Thinking Rubric Score				
			Applied CS data (±s.e.)	Systems Thinking (±s.e.)	Futures Thinking (±s.e.)	Human Agency (±s.e.)	Total (±s.e.)
Setting							
Rural	6	46	2.2 (±0.2)	1.9 (±0.3)	2.1 (±0.2)	2.0 (±0.2)	8.2 (±0.7)
Urban	7	124	1.8 (±0.1)	1.7 (±0.2)	1.9 (±0.1)	1.7 (±0.1)	7.1 (±0.4)
Grade Level							
Primary	5	54	1.9 (±0.1)	1.9 (±0.2)	2.0 (±0.2)	1.8 (±0.2)	7.5 (±0.7)
Intermediate	4	71	1.9 (±0.3)	1.7 (±0.6)	2.0 (±0.3)	1.8 (±0.2)	7.3 (±1.0)
Secondary	4	45	2.1 (±0.3)	1.8 (±0.3)	2.1 (±0.1)	1.9 (±0.1)	7.9 (±0.8)
All groups	13	170	2.0 (±0.1)	1.8 (±0.2)	2.0 (±0.1)	1.8 (±0.1)	7.6 (±0.4)

and monitored snow pack depth monthly in winter using the Global Learning and Observation to Benefit the Environment (GLOBE) protocol (**Figure 2A**; Spellman et al., 2019).

This study falls within the context of a larger research program which is experimentally testing the effects of storytelling-based pedagogies in community and citizen science using a controlled study design. Youth and educators in the storytelling treatment group completed the program with storytelling activities before monitoring berries, during, and after monitoring berries. We compared individual and programmatic learning outcomes to similar groups from similar learning settings and age groups that received the same instructional level of support but framed through standard science inquiry teaching practices. The scenarios storytelling method was used as the final phase in this model. The overarching study used a pre–post design and we could not extract the individual influence of the scenarios method from this controlled study, as the pre–post design encompassed all three storytelling components. The overall effects of the storytelling-based learning cycle for community and citizen science will be presented in a forthcoming manuscript. We present here the available data that could solely address the impact of scenarios storytelling without the influence of the other storytelling methods, as a start to investigating this strategy in more detail and laying groundwork for future study.

Lesson Delivery Method

In the spring after the final data collection had occurred, one scientist and one master educator from our program team delivered hour-long berry data "jam sessions" and scenarios story development activity with each of the thirteen youth groups to explore the data from throughout the state. During the sessions, youth looked at the condition and abundance of berries using the data they collected at their own field site and compared them to data collected at other sites by other volunteers from at least three other bioclimatic regions in Alaska (**Figure 2B**). Guided by program scientists in a space-for-time substitution exercise, they used temperature and precipitation projection scenarios from their own region (Scenarios Network for Alaska and Arctic Planning [SNAP], 2021) and used patterns from the citizen science data in bioclimatic regions similar to the projections (**Figure 2C**) to imagine 20 years in the future.

Based on the data and their knowledge of the sites, students brainstormed what key factors and trends might impact the berry harvests in their community. These lists provided the foundation for the students to imagine what future berry harvest might look like. Students sketched or wrote two contrasting scenarios for the future of berries at their field site or in their community: (1) a do-nothing, business-as-usual future and (2) a "best" berry future. Students began with the do-nothing future, and imagined a scenario with warmer and wetter fall seasons with increasingly rotten, damaged or missing berries as indicated by their datasets they examined (**Figure 2D**). They were prompted by the questions, "What is the data suggesting could happen to our berries?" and, "What will you and the habitat look like 20 years from now?" The students were then prompted to brainstorm ideas for creating different futures, where actions were taken to ensure enough berry resources were available for future generations. Each student thought of three to six actions that they or someone else could take and the ideas were discussed as a whole group (**Figure 2E**). Youth then sketched or wrote a new scenario story of a future where they had selected at least one of these strategies to actively create a new future. After listening to the contrasting scenario stories, students voted on which of the solutions seemed most important to pursue in reality (**Figure 2E**). Educators were not required to pursue the actions that the students agreed upon. The detailed lesson plan and materials are presented in Spellman et al. (2018).

The lesson plan adapted the youth-centered scenarios development scaffolds from Cost and Lovecraft (2020) by condensing some of the steps in the scenario planning process, and by reducing the number of scenarios from four to two. These adaptations allowed us to address the time block scheduling constraints of K12 classrooms and afterschool clubs and to apply the method across the various grade ranges involved in our citizen science program. They also allowed us to test the appropriateness of each strategy across the three different age groups. For each age level, we provided developmentally appropriate strategies to the activity, such as activity sheets modified for very young children and different type, which are documented in Spellman et al. (2019).

To demonstrate this method and explore its application and possible learning outcomes in formal and informal learning

FIGURE 2 | Method for pairing community and citizen science with scenarios storytelling. During the first phase of the activity, students reflected on the berry data they collected in their own field sites **(A)** and analyzed the patterns using graphs **(B)**. They compared the patterns in their site to three other sites in the citizen and community science project from other bioclimatic regions **(C)** to begin to imagine future scenarios of a "do-nothing future" and a "best berry future" **(D)**. Youth collaborators brainstorm strategies to foster a sustainable amount of berries for future generations to include in their scenarios, and prioritize the actions through a voting activity **(E)**. Full lesson plan available from Spellman et al. (2018).

settings, we assessed the activity's impact through educator interviews and analysis of student work samples. While we did conduct youth interviews as a part of our larger study, youth did not mention the scenarios stories exercise in their interviews. They unsurprisingly focused on the activities which they spent the vast majority of their project time on, outdoor data collection. We therefore isolate our data to the student work samples from the scenarios activity and educator interview sections that specifically addressed the scenarios storytelling to cross-validate the evidence.

Student Work

We collected scenario work from all 170 students across the thirteen youth groups. Because some of the groups chose to do the activity as small groups of students rather than as individuals, the total number of work artifacts was 126. Each work sample was evaluated by two reviewers for resilience thinking skills [(1) application of citizen science data to the berry harvest problem, (2) systems thinking, (3) futures thinking, and (4) human agency to act or make change] demonstrated through the activity using a three-point rubric adapted from the validated instrument used in Spellman et al. (2016). The rubric constructs consisted of the four resilience thinking skills listed in **Table 1**, and the rubric criteria spanned three rubric levels for a total of twelve possible points. The rubric is included in Appendix A.

The inter-rater reliability of the adapted rubric was determined by calculating the total rubric scores across the four thinking skills for the work sample, then comparing the scores of the two raters using correlation (Pearson's r). Reliability of each individual rubric item was calculated using Cohen's kappa. The evaluators (Cost and Spellman) first calibrated coding with each other by discussing the rubric scores they individually scored together and discussed differences in interpretation. One scorer (Spellman) had been involved in the delivery of the lesson with all but one of the groups, and conversations about the work with the youth enabled a different insight into the work, and generally led to scores one point higher than the scorer who had not interacted with the students. As a result, we averaged the two reviewer scores for each thinking skill and total score across skills. We then calculated averages across students in each youth group for all further analyses to avoid having urban classrooms with large sample sizes have undue influence on the analysis.

While the use of the rubric was intended to simply assess if resilience thinking skills could be exercised by students through this method, we were interested in whether the method could be applied across many different types of youth groups. To gather preliminary data on its application across age groups and settings, we conducted Analysis of Variance on the rubric scores to test for differences between samples that included group work and individual work, and for the influence of group size and group age range (many youth groups and classrooms in Alaska's rural villages span multiple ages due to very small population size) on the scores using Analysis of Variance. We used the four rubric thinking skills and the total resilience thinking score as the response variables. To better understand student views of themselves as agents of change, we collected additional data on the types of stewardship actions proposed, whether they pictured themselves as agents or beneficiaries of these actions.

Educator Interviews

Our external evaluator conducted post-participation semi-structured interviews of the educators leading each youth group, with eleven of the thirteen educators completing interviews. The interview protocol was a part of our larger citizen science program evaluation, and included a section about the data jam and scenarios storytelling activity. The questions in this section were designed to learn about the educator's perceived effect of the data jam and scenarios storytelling activity on the students and the effectiveness of the activity delivery by the program team. On these interview transcript sections, we coded them first according to the *a priori* resilience thinking constructs to triangulate evidence from the student work samples. We then conducted a thematic analysis as per Terry et al. (2017) for emergent themes. This process involved two researchers and followed a process of, (1) familiarizing ourselves with the quotes, (2) generating codes together, (3) developing themes through an iterative and collaborative process of examining the codes and associated quotes and combining or clustering codes into more general patterns, and (4) assigning themes to each of the quotes.

All statistical calculations were conducted in R studio. All work was formally reviewed and approved by the University of Alaska Fairbanks Institutional Review Board.

RESULTS

Youth Work Samples

Rubric Reliability

Total resilience thinking rubric scores were correlated (Pearson's $r = 0.55$), and Cohen's kappa for the four resilience thinking skills confirmed fair agreement between the two raters ($\kappa = 0.10$ use of citizen science data, $\kappa = 0.23$ systems thinking, $\kappa = 0.16$ futures thinking and $\kappa = 0.28$ human agency).

Demonstration of Resilience Thinking Skills

There was evidence of all four of the resilience thinking skills in the student work samples, with average rubric scores in all four constructs at or near a level two across all youth (**Table 1**). There were no significant differences in individual skill scores or total rubric between age groups or rural and urban learning settings ($p > 0.10$ in all cases). There was no significant difference in the total resilience thinking score if students worked cooperatively or individually in level of resilience thinking rubric scores ($F(1,123) = 1.34$, $p = 0.25$). Group size and number of grade levels within the classroom or youth group did not significantly influence the total resilience thinking rubric scores (group size $F(1,11) = 0.37$, $p = 0.55$; grade span $F(1,11) = 0.13$, $p = 0.73$).

Self as Agent of Action

55.6% of the all youth work samples included the youth themselves as agents of change in their scenario stories (70 of 126 samples; **Figure 2**), while 16.7% (21 of 126 samples) included themselves in their scenarios as beneficiaries of positive change with no indication that they themselves had played a role in it. 27.8% of the samples did not include the youth pictured or described in the scenario (35 of 126 samples). Grade level did not influence the percentages of students who pictured themselves as agents of change in their scenario stories (**Figure 3**; $F(1,11) = 0.1274$, $p = 0.73$). Rural youth tended to include themselves in the scenarios as agents of change at a higher percentage than urban youth (**Figure 3**), though this was not a significant effect. A higher percentage of the scenario stories included the youth themselves as agents of change if they worked on the scenarios as a group then if they worked on it as an individual (63% of group and 53.8% of individual work samples).

Of the youth work samples, 71% illustrated some clear action or strategy to sustain berries into the future taken by themselves or others (**Figure 4**). The most common action that the youth from both urban and rural settings and across age ranges decided to take in their scenarios were agricultural solutions with native subsistence berries species that they monitored (planting berries, berry greenhouses, etc.; **Figure 4**). Other action strategies included further data collection or new technologies to understand the impacts of climate change on berries and using traditional methods for ensuring berry availability in sparse years such as food preservation and berry trading with other regions of the state with different climate patterns. Some youth chose to create protected areas for berries or introduce new non-native berry species. General care for the Earth, such as not littering and "taking care of the berries" were suggested by early primary youth, while climate change policies and related actions were suggested by some of the older youth. While nearly all scenario stories illustrated clear differences between the do-nothing and the best berry future scenarios, 29% did not illustrate or describe an action taken.

Educator Perception

With regard to the activity exercising resilience thinking skills, the educator interviews generally corresponded with the assessment of the student work artifacts. The application of new data received the most attention from educators (21 mentions from 10 of 11 educators interviewed), followed by educator perception that youth exercised futures thinking (15 mentions from 9 educators). The educators also perceived youth practiced systems thinking and expressions of human agency in the social-ecological system, but to a slightly lesser extent than the other two resilience thinking skills (8 educators and 12 mentions, and 6 educators and 15 mentions, respectively).

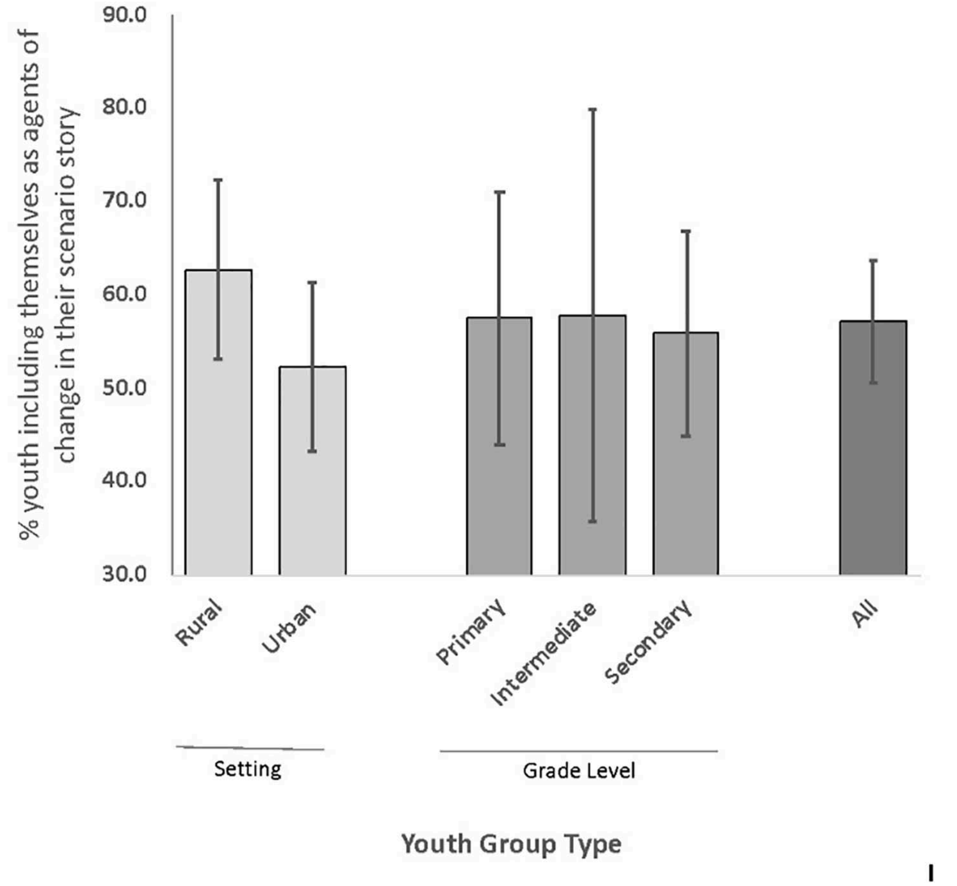

FIGURE 3 | Percentage of youth work samples (n = 126) illustrating youth themselves as agents of berry stewardship action from rural and urban Alaska learning settings and from different grade levels (primary = grades K-3, intermediate = gr. 4–6, secondary = gr. 7–12).

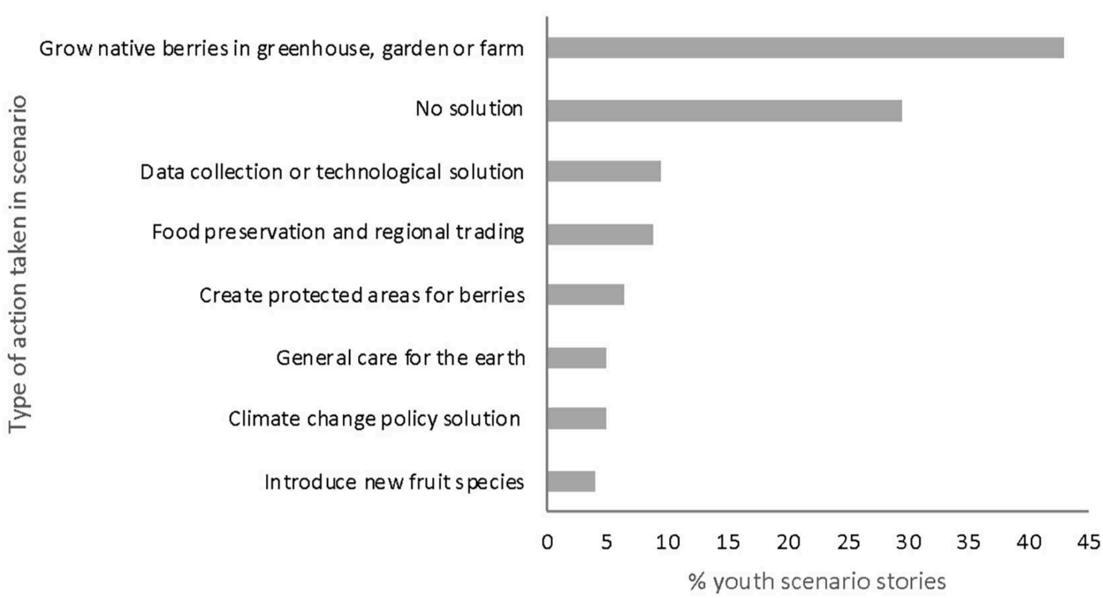

FIGURE 4 | Types of actions illustrated or described in the youth scenario stories (n = 126 youth work samples).

The emergent themes in the educator interviews clustered around two dimensions: (1) perceived effects of pairing community and citizen science with scenarios story development on youth and (2) perceived value of the activity to teaching practice.

Effects on Youth

The most mentioned effect on youth by the educators was that the students felt like they were a part of something bigger than themselves. The community and citizen science aspects of the project enabled the youth to realize they were part of a statewide Winterberry science effort and international network through the inclusion of GLOBE. The educators perceived that this, in combination with the scenarios stories activity, allowed the students to feel like they were a part of creating a positive future for their community. As one educator put it, "*The kids really bonded together in order to make the project very much their own, which is kind of cool considering that it's such a far flung project and involves so many areas within the state of Alaska and that it's science that's shared around the world. It's really cool that the students still felt like it was very, very much their own project. And then also felt that sense of greater community and participation because of all of the other areas where data is collected and the data is used.*" (Educator Interview).

As in this exemplary quote, the sense of "being a part of something bigger" was often mentioned in conjunction with a sense that the students felt empowered by the experience. Educators mentioned that the students were equipped to actually be scientists, change makers and stewards of the land. They saw the youth make decisions using data as they outlined a path to a positive future. "*It just got kids thinking about this future in a positive way. You know, it's not all doom and gloom but–so maybe when they do see berries in the future they will, you know, say, 'oh, yeah. We studied this. We need to take care of these.'*" (Educator interview).

Educators also frequently mentioned that they felt the combination of the berry data collection, analysis and scenarios stories activities enabled youth to connect their learning to their community, their culture(s) and their futures. Culturally important berry species, the focus of the data collection, was noted as the primary source of this connection. They valued the activity as a way to be connected to the land by planning to protect traditional food resources in a changing climate. This aspect was predominantly expressed by teachers in rural and Indigenous communities or Indigenous educators (5 of the 6 educators who mentioned this theme). For example, one teacher from a small remote village stated, "*They all had some little cartoon drawings there with the berries, and that's when they led into their discussion on sustainability and how are we sustaining our–making sure that we have these berries 20 years from now, 50 years from now, in their future. They went through all that, overharvesting, can we plant them, do they just grow naturally? How do we preserve them? How do we use them in our foods? Cultural reasons they're valued. We invited the community up for some cranberry bread. The kids were showing off their data, and they were making more of those picture scenarios for them and kind of promoting [.] taking care, being stewards of the berry.*" (Educator interview).

Other examples included connections to Indigenous foods and language, connecting words of the Elders to the data and to the future, and communicating the results and the scenario stories back to their community or at professional science meetings.

Value to Teaching Practice

The educators who tested this method all perceived desirable teaching practices that resulted from this novel combination of community science and scenarios stories. Most frequently mentioned was the physical presence of a scientist during the delivery of the workshop. The educators thought this was valuable to the practice because the physical presence of the scientist showed youth they were part of something substantial and collaborative with scientists and an effort bigger than themselves. "*The most valuable thing was just them being here as the chief scientist of these projects, and that made an impression on the kids. And the other impression was that I think [the scientists] are very good at making sure that kids understand that they are also scientists, citizen scientists, and they're being stewards, so to speak, of maintaining the data collection and maintaining the integrity of the protocols.*" Additionally, the teachers noted the value of having the additional adults working with the youth to implement the activities. An urban educator stated, "*The most valuable aspects of the work was the scientist coming into the classroom and doing those story activities with those materials directly relating back to the project. That was very valuable because that helped place it into a larger context, not that I can't–I mean, I can certainly–I'm certainly capable of doing that on my own, but you know, the amount of requirements in lesson planning that I have to do on my own behalf makes trying to do these–you know, make a whole 'nother project happen really difficult. So any support that can come from outside to make those things happen is great.*" To do citizen science in youth learning settings well, the educators valued collaboration from outside of the classroom and external support for the science knowledge base and adult to student ratio.

They appreciated that combination of community science and scenario stories creating something "tangible" for the youth. Tangible in the sense that the activities facilitated students moving, learning outside, and using their hands by both counting berries weekly, and by sketching their possible futures and voting on the most important stewardship actions. Tangible also in the sense that the activities related climate change concepts in a way that was real, site-based, and approachable. One teacher stated, "*They just do an amazing job with students, and they were just a breath of fresh air when they came in and made science seem simple, but you know it's technical stuff.*" The climate change impact was easily imaginable in the berries they counted, in the graphs from other communities by youth in other parts of Alaska, and in the climate projections. The solutions the youth brainstormed were real and, for the most part, possible.

The educators appreciated that the pairing of activities was interdisciplinary and applicable across a wide range of ages. The community science data collection on berries combined with the scenarios story strategy allowed them to connect the project across content areas and standards for classroom teachers, or program priorities for afterschool programs (4-H, Boys and Girls Club, etc.). One classroom teacher mentioned, "*We've used it to further develop graphing skills, math skills, looking at data collecting, finding mean and average, you know? All that stuff. Writing. We've been using it in writing. We started the year out with personal narratives, so that they could create those berry narratives that they did* [. . .]" Educators noted that the activity utilized math, science, art, geography, and language arts and could be easily connected to ongoing or current learning and activities within their classroom or clubs. This approach made it an easy fit for addressing cross cutting concepts and themes, such as those emphasized in the Next Generation Science Standards in classrooms or priority youth development goals in youth clubs. In another example, one educator highlighted the concept of stability and change through time: "*Those numbers change and just trying to find patterns and trying to find some connection, some key. I mean we know–you know, we keep telling the kids that it's not what it used to be, you know, that's what we know from the Elders and from people that have been here forever. We know it's not what it used to be but maybe we can see where it's going and what we can do to make it better*." This example both highlights the cross-cutting concept in science education standards, but also how it can be applied to the future. Another afterschool club educator mentioned connecting the experience to healthy eating and diabetes, a priority concept for the rural Boys and Girls Clubs.

The evidence from the interviews also indicated that the activities were applicable across the K-12 age range, and appreciated the easy adaptations that the program provided to accommodate older or younger children. For example, an educator of 5 and 6 year old children stated, "*[The scientist] went around before she passed them out and drew a little sad face on the right and a smiley face on the left [for the better future]. And that was a good adaptation that worked out great*." While in a free-choice learning setting, youth of different ages gravitated to different aspects of the activities, "*It really depended on the age groups like I said, the middle schoolers, high schoolers were more into the social thing [.] The younger ones seem more interested in the data and locations and stuff like that*." In this case, the older students prepared berry muffins for a community story sharing event, while the younger students prepared the data and scenario stories.

From Participating in Science to Stewardship Planning and Action

In addition to the very high percentage of individual youth who successfully planned a pathway to action within their scenarios, all the youth groups were able to prioritize an action strategy across the whole group that seemed the most worthy of investment. Of the thirteen youth groups with whom we piloted this method, eleven of the groups (spanning the entire age range) hosted or participated in community nights or presented at Tribal or community council meetings. Partnership with the Winterberry program team was critical to most of these events. Three groups (two secondary and one intermediate aged) went on to present their work at professional environmental science meetings within Alaska or at a GLOBE regional student research symposium.

Of the strategies identified by the youth for sustaining berries into the future, three strategies were actually implemented by the groups: food preservation, agriculture, and continued monitoring. Two groups preserved berries for lean berry years through jams or drying, and one group planted new cultivars of berries in their school garden to test berry production and fruit condition compared to the wild berries in their school yard. Twelve of the thirteen groups continued to monitor berries through the Winterberry program for at least one additional year, which was expected for the program. Surpassing the program expectations, nine groups continued for three or 4 years, with several educators joining multiple community science projects offered by the University of Alaska Fairbanks team. For example, several educators have joined our ice monitoring program and joined GLOBE to use community and citizen science as a way for their youth groups to investigate other locally relevant topics like changing river and lake ice, water quality in their salmon streams, and soil moisture in tundra habitats.

DISCUSSION

Our results suggest that pairing community and citizen science with scenarios stories in youth-focused programs is a promising method for connecting the data collected to thinking about and planning for the future. We found that the method could be applied usefully across the full K-12 age range, and in diverse learning settings – from small, rural, multiage after school clubs and classrooms in Alaska Native villages, to large urban single grade classrooms with highly diverse student populations. The method afforded the range of students the opportunity to exercise the critical futures thinking skills and competencies proposed by the literature for navigating a rapidly changing climate. Both the educator interviews and the assessment of youth work samples showed that the method provided opportunities for youth to use and apply scientific data, practice systems thinking and futures thinking, and demonstrate human agency in the social-ecological system.

Youth are an important key to the present and future of climate change justice, science, and action (Gibbons, 2014). While climate education programs often have a polarizing effect on adults (Moser and Dilling, 2007), they do not on children and youth, who tend to increase in hope with greater exposure to climate change education despite differences in worldview and socio-ideological background (Stevenson et al., 2018). Further, children can foster intergenerational learning within their families that can overcome socio-ideological barriers to climate change learning among parents and adult caretakers (Lawson et al., 2019). The rapid growth and development of youth, too, has interesting parallels with the rapidly changing ecosystems (Cost and Lovecraft, 2020). Youth are in the midst of change themselves, and may have greater flexibility in cognition, imagination, and adaptation in their response to the changing environment than adults.

Our results from testing this method, however, indicate that thinking about actions to create a positive future in a changing climate is a skill that needs to be practiced. 29% of the youth work artifacts did not include a solution or stewardship action strategy and only 55% explicitly illustrated or described themselves as an agent of change in their scenario stories, despite both being explicit in the lesson instructions. Similar results emerge in other studies of youth engaged in scenarios development (Cost and Lovecraft, 2020; Velarde et al., 2007), futures thinking (Hicks and Holden, 2007) or community and citizen science (Ballard et al., 2017). Youth have a difficult time imagining actions that will make a difference for the future (Cost and Lovecraft, 2020; Velarde et al., 2007; Hicks and Holden, 2007). Similarly, understanding that community and citizen science can lay a foundation for individual and community action is a challenge for youth (Ballard et al., 2017). Reinforcing these attitudes within community and citizen science programs will take deliberate design of supporting activities, such as this one, that can be easily delivered and adapted to a broad array of learners and learning settings. Educators in our study clearly valued the design of this method which provided many interdisciplinary engagement points across an entire year and the physical presence of a scientist. These created more opportunities to connect the youth science work to "the bigger picture" of environmental science and stewardship.

Continuing data collection for multiple years and communicating scientific results and scenario stories were the most common stewardship actions actually pursued by the youth groups (12 of 13 groups and 11 of 13 groups, respectively). Far fewer actually took actions from their scenario stories and pursued them; one group planted berry crops in their school garden and two preserved berries. Data collection and communicating science are more easily achieved by youth groups, with far less energy, time and financial resources required than to pursue a unique path through a self-determined action project. The ease in undertaking these actions, however, may not be the only explanation. In interviews and observational studies of two youth focused community and citizen science programs, Ballard et al. (2017) found that youth involved in community and citizen science projects tended to focus more on collecting high quality data according to the protocol, and developing a sense of expertise in a project than they did on the ways that they could use the experience as a foundation for personal or community change. This trend was also seen in our data, with the application of new data in scenarios stories was evident, and educators mentioning the data collection and application of the data more than the other thinking skills practiced through the activity. This is not surprising, as youth and educators spent the majority of their time during the project conducting data collection.

Motivation is a major driver of both participation in community and citizen science (Rotman et al., 2012; West and Pateman, 2016) and volunteering for environmental stewardship (Bruyere and Rappe, 2007; McDougle et al., 2011; Jacobson et al., 2012). The Winterberry program provided structural support and incentives for youth group participation in the community and citizen science aspects of the project, but did not actively facilitate or support in-depth stewardship planning or action beyond the hour long scenarios lesson. If this method were to be applied in settings without the structural constraints of classrooms and afterschool clubs, further study into the role of motivation and incentives, and intentional program design for supporting community and citizen science volunteers in stewardship action or policy advocacy would be recommended. In our study it was clear in both youth and educator datasets that the concern for the future of berries was present, and the actual pursuit of some actions beyond what was expected in the program was promising. However, the time and curriculum constraints in structured youth programs likely limits what can realistically be done even if motivation is high. Further, the time costs and motivations for implementing this method would shift if an educator chose to implement the activity themselves rather than having a citizen science program staff come in to deliver the lesson, as we did in our implementation.

The slight differences in youth who pictured themselves as agents of change in their scenario stories in rural settings and in group work are worth further analysis in future examination of this method. While most Alaskans in both rural and urban learning settings have experiences harvesting wild berries for food and recreation, the rural youth groups are surrounded by much smaller closer-knit communities where each individual has a role in the functioning of the community, and the cultural connection to berry resources is robust. This could influence the sense of agency in these youth. Group work also slightly increased the percentage of work samples that included the youth taking stewardship action compared to when they worked individually. This is despite the fact that all students participated in the deliberation as a group before working on their scenarios, and the time frame for the activity was kept constant across the groups. This may also be the result of youth working in groups feeling like they needed to be represented in the group work, while they had a different sense of ownership over the project when they worked on it as an individual. Educators also emphasized the effects of the group of students "making the project their own." Together these findings suggest that collaborative and social learning processes are important to this method, a point increasingly emphasized in the environmental education literature (Krasny and Tidball, 2009; Lebel et al., 2010; Bestelmeyer et al., 2015; Krasny, 2020).

To truly create community and citizen science for the future, we must engage youth in both the process of science and the process of using that science to guide us to a positive future. Our work supports the idea that pairing community and citizen science and scenarios development provides a concrete strategy for allowing youth to practice resilience thinking and imagining themselves as agents of change. It is a promising approach to help citizen science volunteers see how their data can inform planning and decision making to help create a positive future.

DATA AVAILABILITY STATEMENT

Only anonymized data summaries may be provided upon request and any data sharing will seek approval by the University of Alaska Fairbanks Institutional Review Board.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Alaska Fairbanks Institutional Review Board (1062412-5). Free prior and informed consent was obtained by adult educator participants and the legal guardian of the youth. Youth in the fourth grade or higher also provided their own signed informed consent to participate in the study. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

KS, DC, and CV contributed to the idea development, writing, and revision. KS and DS conceived and completed the analysis. All authors developed the methods and completed the field testing and data collection.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2021.695534/full#supplementary-material

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