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Redistributing Power in Community and Citizen Science: Effects on Youth Science Self-Efficacy and Interest

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Abstract: Youth-focused community and citizen science (CCS) is increasingly used to promote science learning and to increase the accessibility of the tools of scientific research among historically marginalized and underserved communities. CCS projects are frequently categorized according to their level of public participation and their distribution of power between professional scientists and participants from collaborative and co-created projects to projects where participants have limited roles within the science process. In this study, we examined how two different CCS models, a contributory design and a co-created design, influenced science self-efficacy and science interest among youth CCS participants. We administered surveys and conducted post-program interviews with youth participation in two different CCS projects in Alaska, the Winterberry Project and Fresh Eyes on Ice, each with a contributory and a co-created model. We found that youth participating in co-created CCS projects reflected more often on their science self-efficacy than did youth in contributory projects. The CCS program model did not influence youths' science interest, which grew after participating in both contributory and co-created projects. Our findings suggest that when youth have more power and agency to make decisions in the science process, as in co-created projects, they have greater confidence in their abilities to conduct science. Further, participating in CCS projects excites and engages youth in science learning, regardless of the CCS program design.

Keywords: public participation in scientific research; learning outcomes; berry monitoring; freshwater ice monitoring; education; co-production; community-based monitoring; environmental monitoring; environmental education; equity

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1. Introduction

As the field of community and citizen science research grows, more attention is being paid to the relationship between project design and outcomes that support sustainable development goals. While community and citizen science has long been recognized and promoted as a strategy to increase the amount and types of data scientists have access to [1], it is also becoming popular as a way to promote science learning [2] and to engage historically marginalized and underserved communities in scientific research [3]. These areas of growth in the field have great potential to support the United Nations' Sustainable Development Goals of high-quality education (SDG4) through place-based learning and reduced inequalities (SDG10) by offering some level of local control and ownership over data being collected [4]. These expanding uses of community and citizen science necessitate a closer examination of how these projects are designed, the power structures implicit in the design, and how these influence the learning and science outcomes. We use the term *community and citizen science* intentionally: *community science* focuses on science by and for local people, with the goal of improving local community conditions [5], while *citizen science* is broadly defined as the non-scientific public working with scientists on research [6]. Put together, community and citizen science (CCS) encompasses the community-based nature of the type of science examined in this study, which was characterized by support and coordination by scientists and deep local engagement to benefit communities. In this paper, we look at how the distribution of power across two different types of CCS program designs influences youths' learning outcomes.

1.1. Equity in Community and Citizen Science Design

Community and citizen science projects are frequently categorized according to their level of public participation and distribution of power between professional scientists and public participants: contractual, contributory, collaborative, co-created, and collegial [7,8]. In *contributory projects*, for example, scientists determine the research questions and data collection methods and analyze and interpret the results, while community members select the sites for data collection and collect the data [8]. In *co-created* projects, the balance of power shifts: community members and scientists make decisions together about which questions will be investigated, how data will be collected, and how the results will be used [8]. These typologies assist CCS practitioners with design considerations, such as required resources and decision-making processes, and learning outcomes vary across the different program models in the spectrum [9].

As the number and scope of CCS projects continue to expand [10,11], it is necessary to consider the distribution of power across existing and new CCS projects, and the implications for who participates and who does not. In the United States, the majority of citizen science volunteers are white, middle-aged, retired, highly educated, and reside in urban or suburban areas [3,12]. Calls to diversify the field of CCS, as well as to use this type of scientific research to address relevant, real-world issues are increasing [5,13]. The distribution of power in CCS projects is particularly important in cross-cultural settings, where legacies of power and colonization ripple throughout community governance and sustainable development [14].

In the far north, where climate change is accelerating faster than the rest of the world [15], CCS is an important tool to monitor and respond to local climate change impacts [16,17]. There are important roles for both contributory and co-created CCS projects to play: contributory projects can be deployed rapidly and gather large amounts of information across the vast and remote northern geography, while co-created projects allow for deep engagement with local issues in specific communities [18]. Co-creation approaches to developing projects, which can be the start of *co-production of knowledge* between two different knowledge systems, center equitable distribution of power between Indigenous communities and Western scientists, and are increasingly visible and emphasized in Arctic sciences [19,20].

1.2. Youth Engagement and Outcomes in CCS

Community and citizen science is recognized as a rich context for science learning [13], and there are a growing number of youth-focused community and citizen science projects which embrace a wide variety of learning goals [21]. These learning goals range from understanding multiple approaches to the scientific process [22] to using science for civic engagement [23] or taking conservation action [21]. Youth-focused CCS projects often take place in classrooms or after-school clubs [24] and can include a significant curriculum component [25,26]. Contributory projects tend to be favored over co-created projects due to the extra time and resources required to facilitate open and collaborative inquiry.

The youth learning outcomes in contributory projects are well documented. Youth participation in these contributory CCS projects has led to individual learning outcomes, such as increased science content knowledge and mastery of science practices (e.g., developing research questions and using scientific tools) [27,28]. Several studies demonstrate youth engagement in contributory CCS leads to improved *science self-efficacy,* defined as youths' confidence in their science abilities [2], by providing youth with opportunities to participate in data collection using protocols, identify areas of their own scientific expertise, and interpret and apply data [21,29,30]. *Science interest,* or the degree to which youth perceive science to be personally relevant [2], is also documented as an outcome of contributory CCS projects. Some evidence suggests that youths' interest in science-related careers increases after participating in a CCS project [26,27].

Redistributing power in the design of a CCS project may influence youths' science self-efficacy and interest. Previous research on learning through guided inquiry versus open inquiry can help inform the differences between youth learning outcomes in contributory versus co-created CCS projects. In guided inquiry projects, youth are provided with the research problem, while in open inquiry projects, youth are given full ownership over the investigation, from asking the research question to reaching their final conclusions [31]. When youth have the power to ask their own questions, assume the responsibility of designing their own methods, and draw their own conclusions, they have more opportunities to understand the complex and iterative nature of science [32]. Youth participating in open inquiry projects have been shown to feel a greater sense of involvement in the project and collaboration with their peers and have an overall greater sense of satisfaction and personal gain when compared to youth participating in guided inquiry projects [33]. These findings suggest that youth in co-created CCS projects, in which they have the power to ask their own questions and carry out their own projects, may experience deeper levels of learning than youth in contributory CCS projects.

1.3. Aim of Study

In this study, we examined youths' science self-efficacy and science interest development through participation in two CCS programs. Specifically, we investigated how the CCS program model (contributory or co-created) influenced youths' science self-efficacy and science interest. While previous research has examined youth learning outcomes through participation in CCS (e.g., [21,27,30]), we are not aware of any studies that have tested the effects of different CCS program designs (e.g., contributory or co-created) on youth learning. Understanding how each program model influences youths' learning outcomes is important for CCS practitioners because various program models may support distinct youths' learning outcomes, and the resources (time, expense, expertise, and materials) needed to run contributory versus co-created projects are different. Our research question was: how do youths' science self-efficacy and science interest development differ between contributory and co-created program models?

We hypothesized that participation in both program models would increase science self-efficacy and interest among youth, but that participation in co-created projects would lead to greater change in these two learning outcomes.

2. Materials and Methods

2.1. Study Context

This study focuses on participants in two CCS projects monitoring resources that hold cultural and practical significance for people across Alaska. We selected these projects for this study because they engage youth in locally relevant climate change research. The first project, *Winterberry,* monitors native berry species to better understand how the increasingly earlier start of the growing season in Alaska influences seasonal patterns in berry availability and quality in the fall. Berries hold deep cultural significance for many Alaska Native peoples and are an important food source, particularly in remote communities where access to fresh produce is limited [34].

The second project, *Fresh Eyes on Ice,* is similar in structure to *Winterberry* but focuses on river and lake ice. Freshwater ice is essential to winter life in many Alaskan communities; it is important for food security (e.g., ice fishing), travel, and recreation [35]. It is also a source of dangerous unknowns: unstable ice conditions can lead to injuries and death, as when someone falls through thin or unstable ice [36]. Understanding how ice conditions are changing in a warming climate is important for survival in many Alaskan communities.

Data for this study were drawn from interviews and surveys that were collected between 2018 and 2019 (*Winterberry)* and 2021 and 2022 (*Fresh Eyes on Ice)*. We collected surveys from youth across *Winterberry* and *Fresh Eyes on Ice* who participated in contributory projects (n = 321) and co-created projects (n = 137). We interviewed 49 youth from *Winterberry* and *Fresh Eyes on Ice*, spread evenly across contributory (n = 25) and co-created (n = 24) project models.

2.2. Project Design

Through *Winterberry* and *Fresh Eyes on Ice,* we work with Alaskan educators and scientists to engage youth in culturally responsive CCS [37,38]. We use the term *culturally responsive* to mean that we involve youth in science research that aligns with their personal and cultural values and ways of knowing about topics (such as berries and ice) that have social, economic, and/or cultural importance to their communities [39]. Youth in both projects begin their work by recognizing their personal connection to berries or ice through storytelling or sharing prior knowledge on the topic. They listen to and learn from Elders and other long-standing community members to understand how berries or ice, depending on the project, have changed over time. Youth then collect data, analyze their results, and share their findings with a public audience.

For this study, youth in both *Winterberry* and *Fresh Eyes on Ice* participated in two program models, a contributory model or a co-created model (Figure 1). In *Winterberry*, the contributory model was implemented simultaneously with the co-created model. *Fresh Eyes on Ice* was implemented in two phases: all communities in the project first participated in a contributory model one year and then in a co-created model in the next. In the contributory model for both projects, the project scientists provided instructions to community-based monitoring teams of youth and educators about what data to collect and how. The co-created model was implemented with a slight difference between *Winterberry* and *Fresh Eyes on Ice*: in *Winterberry,* educators and project scientists worked together to develop berry-related research questions, based on communities' priorities but without youth input, while in *Fresh Eyes on Ice,* youth were supported by educators and scientists to develop their own ice-related research questions. In all projects, youth collected data at sites in or near their communities to help answer one or more research questions. Some examples of the types of data collected included berry species presence and abundance (*Winterberry*) and ice thickness and snow depth (*Fresh Eyes on Ice).* The interpretation of the data was driven by youth in a collaborative environment, supported by scientists and educators. All youth had opportunities to present their research findings to an external audience, such as at a regional student research symposium or during a community science night.

2.3. Data Collection and Analysis

We used a convergent parallel mixed methods study design [40] to examine how youths' science self-efficacy and science interest changed after participating in a CCS project (Figure 2). Qualitative (interview) and quantitative (survey) data were collected simultaneously, analyzed separately, and compared for common themes. Interview questions and survey items for both *Winterberry* and *Fresh Eyes on Ice* are available as supplementary material (Protocols S1 and S2; Surveys S1 and S2). All protocols were approved by the University of Alaska Fairbanks Institutional Review Board, and youth and parental consent were obtained for all participants.

One-on-one interviews were conducted with a subset of participating youth at the end of each project's season and averaged 20–30 min in length. Interview data were transcribed and then analyzed using Dedoose software. We developed codes to draw out themes related to science self-efficacy and science interest, tested the codes on a subset of interviews, and then refined the codes for our final codebook. We applied codes to a subset of interviews to determine interrater reliability for code application (K = 0.63, Pooled

Cohen's Kappa coefficient) and code weighting (r = 0.98, overall Pearson's correlation coefficient). After achieving satisfactory inter-rater reliability, the three reviewers each coded roughly one-third of the interviews. We additionally coded the interview excerpts with a priori codes drawn from the sources of science self-efficacy framework [41–43] to understand which of the four types of resources youth drew on in the projects to build science self-efficacy: mastery experiences (performing science-related tasks), vicarious experiences (learning by observing meaningful others), social persuasion (confirmation of science capabilities from meaningful others), and physiological reactions (feelings and emotions resulting from engaging with science that impact an individual's beliefs about their abilities). Examples of excerpts and their classifications according to these types of self-efficacy resources are shown in Table 1.

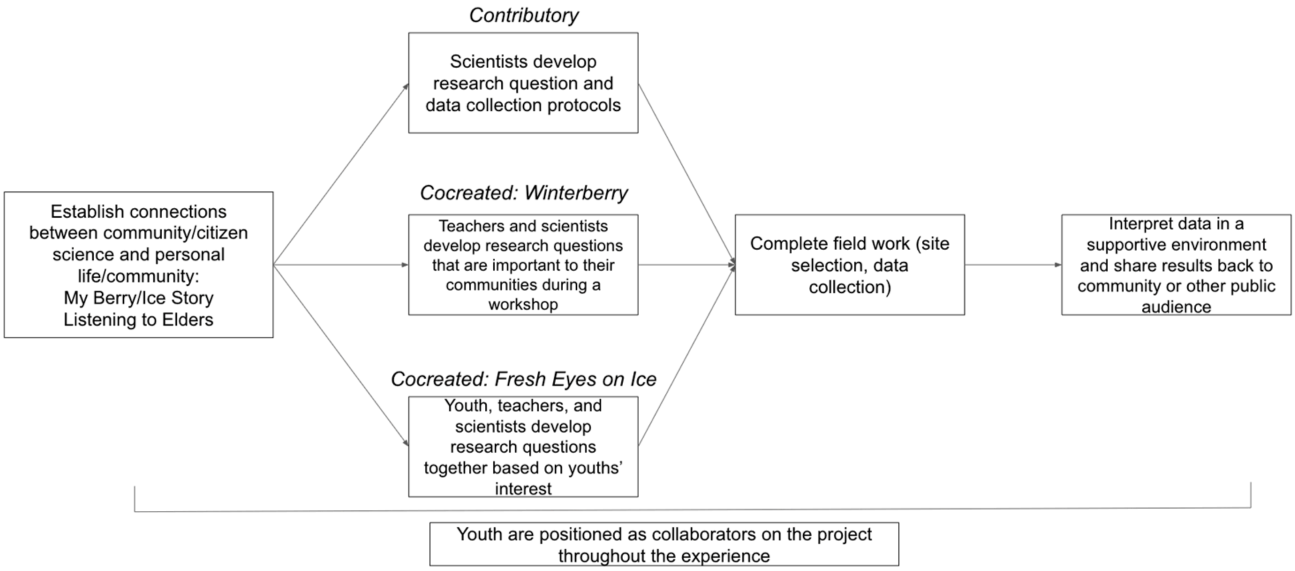

Figure 1. *Winterberry* and *Fresh Eyes on Ice* were each implemented in a contributory and a co-created model.

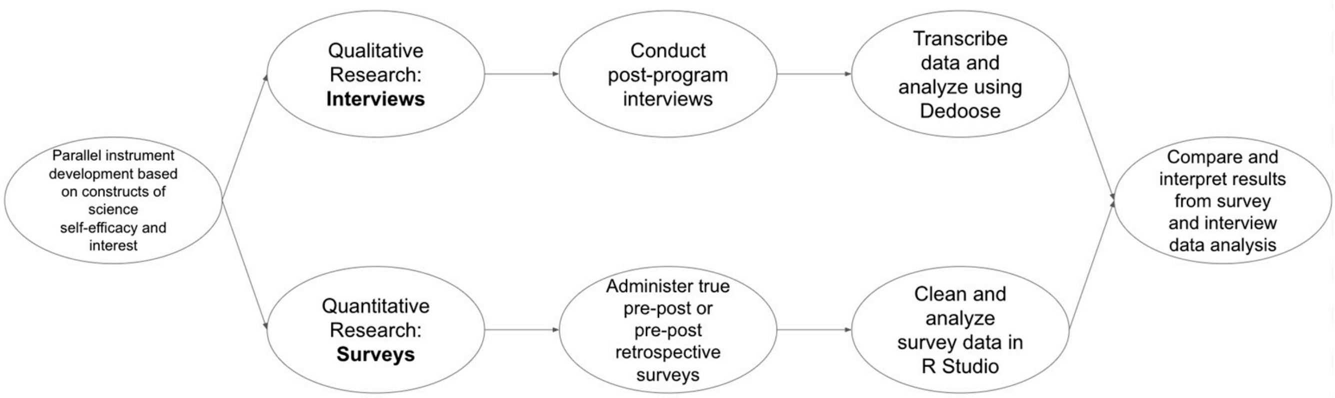

Figure 2. Convergent parallel mixed methods study design.

While the surveys contained the same questions across both projects with the exception of a few project-specific questions, *Winterberry* surveys were administered as true pre- and post-program surveys (Survey S1), and *Fresh Eyes on Ice* surveys were administered as one pre-post retrospective survey at the end of the project's season (Survey S2). We measured youths' science self-efficacy and science interest using five-item Likert scales adapted from the DEVISE (Developing, Validating, and Implementing Situated Evaluation Instruments) project, created and validated by the Cornell Lab of Ornithology [44,45]. The other survey items were developed by co-author K. Spellman and program evaluator A. Larson based on a literature review of citizen science program quality indicators [18,46], and these items are not used in this study. All statistical analyses were conducted in R Studio.

Table 1. CCS program design elements evoking youth science self-efficacy reflection.

Program Design Element Evoking Youth Science Self-Efficacy Reflection	Example Excerpts	Source(s) of Science Self-Efficacy	Nature of Experience
Asking questions	*"I was asking questions, and questions can make you feel like a scientist. And I got a science award [for being the most observant and asking a lot of questions], which made me super happy."*	Social persuasion, physiological reaction	Engaging in a core science practice and being recognized by others for it supported youth's science identity.
	"My whole project was actually prompted by when the kids started asking, why does the water smell that way? Can we figure out what it is? And that's what led to dissolved oxygen and that's what led to my project."	Mastery experience	Youth observations and curiosity provided inspiration for their questions and motivation for their projects.
Doing fieldwork	*"So, once we collected the samples under the bridge, we left. And while we were leaving, that's when I felt like a scientist, because I got to do things some other kids haven't gotten to do before. And that can also lead you to feeling special, to be almost like a scientist."*	Mastery experience	Having field experiences that are different from what they or their peers might typically encounter helped youth see themsleves as scientists.
	*"At the beginning of the ice workshop stuff, [Elder] was talking about science stuff about [knowing] the ice is unsafe to walk on. Like visual and auditory cues that maybe it's not safe. That's probably the biggest thing I learned." **	Vicarious experience	Knowledge shared by an Elder about how to determine safe and unsafe ice conditions was the most personally consequential to youth.
Interpreting data in a collaborative learning environment, supported by scientists and teachers	*"Looking at the numbers at first was kind of frustrating because if you look at the different holes then there's really no correlation. So we were looking at the data in charts and it really wasn't working for us. So that started to get frustrating but after we figured out how to do T-tests on the graph, that formula really helped us and kind of encouraged us to keep looking."*	Mastery experience, physiological reaction	Moments of productive struggle and success during data exploration and analysis strengthened youths' science self-efficacy.
	"I really liked looking at the data and trying to find conclusions from it because even though we have all the data, that doesn't mean it's going to tell us anything. So when we could actually find something that could be useful to us, that felt–it was really the best part."	Mastery experience	Data interpretation provided an opportunity for youth to develop a sense of ownership over the dataset and its use.
Positioning youth as collaborators on the project	*"So when we went on that field trip, right when I made this little wall [in the snow pit], I had taken off my glove immediately to try and ffeel it, and then [project scientist] pointed that out, and she called me Scientist [Name]. I'm like yes, this is what I like."*	Social persuasion	Recognition by a professional scientist affirmed youth's affinity for science.
	"When we were studying which water was the cleanest, the top and the bottom [of the snowpack]. And it made me feel like a scientist because [project scientist], when she came in, she said that she studied that a little bit. So that's how it made me feel a little bit like a scientist."	Social persuasion	Validation by a professional scientist supported youth's science identity.

* Indicates an excerpt from youth participating in contributory projects.

We conducted a pairwise comparison for youths' individual pre- and post-science self-efficacy and science interest survey scores. We then used Analysis of Variance (ANOVA) to determine whether the changes in youths' science self-efficacy and science interest scores were influenced by program model (contributory versus co-created), setting (urban versus rural), or grade level (primary, intermediate, or secondary). For the ANOVA, we used the mean pre- to post-change for the youth group as the response variable. Using the youth group as the unit of analysis, rather than individual students, allowed us to reduce the over-representation of large youth groups from urban areas (often 25–30 students) compared to youth groups from small village communities (often 6–10 students in size) in the sample.

3. Results

We found that youths' science self-efficacy was influenced by the program model (contributory versus co-created), while their science interest was not. Here, we report our findings regarding (1) youths' science self-efficacy and science interest survey scores, (2) how program design elements afford youth opportunities to draw on different sources of science self-efficacy, and (3) various ways in which youths' science interest was kindled by participating in CCS projects, regardless of the program model.

3.1. Surveys

In their surveys, youth in both contributory and co-created projects reported moderate to high levels of science self-efficacy and science interest before participating in the projects and changed little after the program (Table 2). Only youth who participated in Fresh Eyes on Ice showed a statistically significant change in their science self-efficacy and science interest at the end of the project, with a medium effect size for youths' change in science self-efficacy (d = 0.67) and a small effect size for youths' change in science interest (d = 0.43). Neither youths' variation in their science self-efficacy nor their science interest scores were explained by project model, setting, or grade level (Table 3). Overall, it was difficult to detect large differences in either science self-efficacy or science interest between youths' pre- and post-program survey scores.

Table 2. Youths' pre- and post-science self-efficacy and science interest survey scores.

	Pre-Project Mean (s.d.)	Post-Project Mean (s.d.)
Winterberry		
Science self-efficacy	3.54 (0.81)	3.51 (0.80)
Science interest	3.90 (0.76)	3.86 (0.74)
Fresh Eyes on Ice		
Science self-efficacy	3.43 (0.91)	**3.87 (0.87)** **
Science interest	3.74 (0.87)	**4.11 (0.87)** **
Contributory		
Science self-efficacy	3.56 (0.84)	3.54 (0.82)
Science interest	3.86 (0.78)	3.89 (0.74)
Co-created		
Science self-efficacy	3.44 (0.81)	3.63 (0.83)
Science interest	3.90 (0.79)	3.90 (0.83)

** $p < 0.01$.

3.2. Science Self-Efficacy

In their interviews, youth in co-created projects reflected on their science self-efficacy development more often and in greater depth than did youth in contributory projects. We identified four program design elements across both contributory and co-created projects that were associated with science self-efficacy: (1) asking questions, (2) doing fieldwork, (3) interpreting data in a collaborative learning environment, and (4) positioning youth as collaborators. These elements afforded youth opportunities to draw on various sources of self-efficacy: mastery experience, vicarious experience, social persuasion, and physiological reaction [41]. Youth in co-created projects reflected on their science self-efficacy growth more often than youth in contributory projects across three of the four design elements (Table 4). We most frequently applied the science self-efficacy code to excerpts describing interpreting data in a collaborative environment, followed by positioning as collaborators then doing fieldwork, and finally asking questions. In contrast, youth in contributory projects did not describe asking questions or being positioned as collaborators when reflecting on their science self-efficacy, and they associated their science self-efficacy development most frequently with doing fieldwork, followed by interpreting data in a collaborative environment.

Table 3. ANOVA F values for program model (contributory vs. co-created), community location (urban vs. rural), and grade level (primary, middle, high).

	df	Science Self-Efficacy F	Science Interest F
Winterberry		$n = 12$	$n = 11$
Program model	1	2.04	2.33
Setting	2	1.34	0.15
Grade level	1	0.87	0.31
error df = 11 (self-efficacy), 10 (interest)			
Fresh Eyes on Ice		$n = 8$	$n = 8$
Program model	1	0.81	<0.01
Setting	2	0.20	0.64
Grade level	1	1.92	0.12
error df = 7			

Table 4. Frequency of youths' reflections on their science self-efficacy growth across program design elements by CCS model.

Program Design Element Evoking Youth Science Self-Efficacy Reflection	Relative Frequency of Mentions across Interviews	
	Contributory ($n = 25$)	Co-Created ($n = 24$)
Asking questions	0%	8%
Doing fieldwork	12%	13%
Interpreting data in a collaborative learning environment, supported by scientists and teachers	8%	25%
Positioning youth as collaborators on the project	0%	17%

In these interviews, youth who participated in co-created projects reflected on their science self-efficacy when afforded opportunities to take ownership over core science research practices and when recognized and validated by meaningful others (e.g., professional scientists, teachers, and/or peers). Youth further described their feelings associated with these opportunities as feeling happy, special, frustrated, and encouraged. Youth drew most often on mastery experience or their direct participation or action in the scientific process as a source of science self-efficacy. Social persuasion (the recognition of science abilities by others) and physiological reaction (the emotions youth associated with participating in the science process) followed mastery experience as sources of science self-efficacy. Youth rarely referenced vicarious experience or observing experts while describing experiences or feelings of science self-efficacy, which echoes findings in other research [43].

3.3. Science Interest

We coded youth interviews for both science interest, where youth expressed enthusiasm for science generally, and project interest, where youth expressed enthusiasm specifically for the CCS project in which they participated. Youths' interest in science and their projects was one of the strongest outcomes across both the surveys (highest pre- and post-scores) and the interviews (most frequently mentioned). There was no difference in how youth in contributory versus co-created projects described their interest in science and their interest in the project.

One-third of youth expressed interest in science, generally (33%; 16 out of 49 interviews), split between contributory (seven of 25 interviews) and co-created (nine of

24 interviews) models. While several youth stated that they already liked science before participating in their project, most of the youth who reported a broader interest in science talked about how their views of science changed during the project. They described how participating in Winterberry or Fresh Eyes on Ice inspired a change of heart about science, helped dismantle their previously held stereotypes about science, and shifted their ideas about the nature of science (Table 5).

Table 5. Youths' changing views of science as described in CCS program participant interviews.

Youth Perceptions of Science	Example Excerpts
Enjoying science	• *"I wasn't really into science until I went on Fresh Eyes on Ice. Now I'm actually really into science."* * • *"[This project] showed me science could be really fun. And you have to have patience."* • *"I used to not like science that much because that used to be my hardest subject. But now since I've learned more about it, I think it's a lot cooler and I like to do it more."*
Dismantling stereotypes	• *"I always thought scientists would be in the lab, and, you know, make potions and stuff, or experiment on rats, but here, they actually study a lot more stuff."* * • *"I thought, 'oh, [the scientists] are just doing this to get paid.' Now that I think about it, I'm like, 'they're not just doing this to get paid. They're doing this for fun.'"*
Shifting ideas about the nature of science	• *"A lot of science is basically reading stuff. This science is actually doing stuff."* • *"Science isn't always just like medical science or anything. There's way more fields that you can really think about, and even something as basic and taken for granted as ice can still be very interesting and something you should study."* *

* Indicates excerpt from youth in contributory projects.

A total of 78% of youth across both projects (38 of 49 interviews) reported interest in their project, split evenly across contributory (19 of 25 interviews) and co-created (19 of 24 interviews) models. The two most common reasons youth gave for being excited about their project were (1) completing their projects outdoors (39%; 19 of 49 interviews) and (2) the opportunity to use science tools such as shovels and flagging tape (Winterberry) and ice augers, snow probes, and measuring tapes (Fresh Eyes on Ice) (35%; 17 of 49 interviews).

Several youth made positive connections between their projects and their worlds outside of school. One youth said, "I like being outside, and the information that I gather is so relevant to the things that I do, that it drug me into it further and stuck me into the project" (Contributory). Another reported, "[I most enjoyed] the fact that you connect with nature by walking outside instead of sitting in boring classrooms . . . it's cool to learn about something that's in your backyard instead of learning about something that's happening across the world" (Contributory). Youth also talked about their enjoyment of working collaboratively, both with their peers and, in some cases, with younger students. As one youth put it, "I thought it was fun when you worked with other people . . . you have all this work on you that's hard to do. And then when you get stuck, there's other people there to help you" (Co-created).

4. Discussion

4.1. Effect of Program Model on Youths' Science Self-Efficacy and Science Interest

We set out to understand if and how contributory and co-created CCS project design influenced youths' science self-efficacy and science interest. We found through the youths' interview data that participation in co-created projects led youth to reflect more often on their science self-efficacy than youth participating in contributory projects. While participating in CCS projects generally led to an increase in youths' science interest, this increase was not influenced by the program model.

4.1.1. Science Self-Efficacy

Youth in co-created projects reflected on their science self-efficacy development more frequently, and in connection with a wider variety of experiences within the program, than youth in contributory projects. Youth who participated in co-created projects developed more confidence in their science abilities when they and their adult collaborators had the power to collectively choose projects that mattered to them. This increased confidence in youths' science abilities has been demonstrated in youth participatory action research, another form of youth-led research in which youth have more decision-making power in the research process [47].

We saw that youth reflected most often on their science self-efficacy when interpreting and analyzing data compared to other program design elements and activities. This may be, in part, because manipulating data is one of the less familiar steps in the scientific research process for students and teachers [48,49]. A 2017 literature review of youth participatory action research found that only 11% of studies reviewed involved youth in data analysis [50]. This may shift as the field of data science education, including the types of data and tools for analysis youth have access to, continues to grow [51]. Data analysis for the youth in our study often involved using math, and youth had to draw on skills learned in previous math classes (as one youth in a co-created project described) or learn completely new skills, like how to perform a t-test (as another student described). Math anxiety, or the fear students (and teachers) may feel about doing math, is regularly found to be high among students in the United States [52,53]. We believe that these youth having an opportunity to practice math and science skills alongside a scientist while manipulating their own data led to an increase in their science self-efficacy.

Youth analyzed their own data to find, as one youth described it, "*something that could be useful to us*" (Co-created). Our findings suggest youth have more confidence in their abilities and ownership over the process when the data are *theirs.* This phenomenon is similarly described in previous research as *higher authorship proximity* [54], which describes youths' closer relationship with data that they have personally collected, as well as their stronger sense of agency with the data. In other studies, increasing youths' sense of ownership of their data has led to youth taking action on issues in their communities related to energy production and conservation [23,55]. In previous research on adults involved in different models of CCS, one study found that environmental resource decision-making and action occurred three to nine times faster when local community members were involved in data collection, analysis, and interpretation in environmental monitoring CCS projects, compared to when scientists directed similar projects [56]. These studies, in addition to ours, suggest that the more ownership over the data in CCS projects, the greater the benefit to participants' self-efficacy and agency.

4.1.2. Science Interest

We found that youth enjoyed participating in CCS projects regardless of the program model and attributed their interest to several specific design elements. These included doing CCS projects outdoors in familiar environments (school yards, backyards, local communities, etc.) and getting to use science tools. Community-based and place-based learning research has demonstrated that learning science outdoors, and in familiar places, enables youth to understand science as personally relevant and important to learn [57,58].

Working with science tools in an authentic research setting has been shown to help youth engage in science identity work [59,60]. Youth across both contributory and co-created projects also expressed enthusiasm for the autonomy they were given over their data collection and analysis. Our findings suggest that, regardless of the program model, participating in CCS projects led to an increase in youths' interest in science and greater enjoyment of the projects.

4.2. Strengths and Limitations of Our Mixed Methods Approach

We used a mixed methods study design in which we used surveys to obtain a broad understanding of the impacts of the CCS projects on participating youth and interviews to gain a deeper insight into the experiences of a subset of youth. The survey data and interview data showed strikingly different levels of richness: in the survey data, we could not detect whether participating in CCS projects influenced youths' science self-efficacy and interest, regardless of the program model. The interview data, by contrast, revealed substantial differences in youths' science self-efficacy between program models, and demonstrated that youths' already moderate to high interest in science did not increase, nor did it differ by program model. In the future, we hope to focus more on qualitative research approaches with younger youth. Other researchers have found qualitative approaches to be more representative of youths' perceptions and mindsets [47,61].

While we did not detect a pre- to post-program change in survey data between youth in contributory versus co-created projects, we did find a difference between the *Winterberry* and *Fresh Eyes on Ice* surveys. The *Winterberry* surveys, which were administered as true pre-post surveys, did not show significant pre-post changes in youths' science self-efficacy or science interest. The *Fresh Eyes on Ice* surveys, administered as a single retrospective pre-post survey at the end of the program, did show significant pre-post changes in both learning outcomes. We propose that this difference may be explained by our administration of surveys between projects. There are known issues with both types of survey administration [62]. True pre-post surveys have problems with response-shift bias [63], while retrospective pre-post surveys are prone to biases like respondents misremembering events or reporting what they believe survey administrators want to hear [64]. In a small-scale follow-up study, we used the same DEVISE survey items for science self-efficacy and science interest and compared youths' (n = 34) true pre-post and retrospective pre-post surveys, and we found that, in general, there was a greater difference in the retrospective pre-post scores, which can help explain the difference we saw between the *Winterberry* and *Fresh Eyes on Ice* survey scores.

4.3. Implications for Youth-Focused Community and Citizen Science Design to Advance Equity and Education Goals

Culturally responsive CCS supports the Sustainable Development Goals. This type of youth-focused research promotes quality education (SDG 4) and reduces inequalities (SDG 10). Our work applying and studying different CCS program designs has led us to identify key components of culturally responsive CCS that may have benefited youths' self-efficacy and interest. These include the alignment of CCS with community priorities, positioning of youth as leaders in the project, and getting youth involved in place-based projects.

4.3.1. Align CCS Projects with Community Priorities

Designing youth-focused CCS science projects that are culturally responsive is a necessary first step to advancing equity. Youth have more positive experiences and learn better when the science content is relevant to their cultures [57,65]. Both *Winterberry* and *Fresh Eyes on Ice* were designed to align with community priorities for food security and ice travel safety in a changing climate in the far north [37].

Culturally responsive education has been shown to provide benefits for all youth, particularly youth from marginalized communities [66]. Our educational curriculum that accompanies these CCS projects prioritizes local and cultural knowledge and engages youth in education about relevant environmental issues facing their communities (example lesson plans can be found at sites.google.com/alaska.edu/winterberry and fresheyesonice.org). Learning through CCS research can reduce inequalities by providing youth in underserved or historically excluded communities with tools to understand and act upon their own changing environments.

4.3.2. Position Youth as Co-Designers of Projects and Leaders in Data Analysis

We found that empowering youth to take on leadership roles in designing and implementing CCS projects afforded them opportunities to deepen their beliefs in their science abilities and increased their sense of stewardship over the project and its outcomes. This type of co-created project takes a greater investment of resources, such as time, money, and expertise [8], and may not always be possible in youth-focused settings like classrooms or after-school programs [24,67]. However, even a partial transfer of power to youth over some aspects of the project, such as leading the analysis of project data, may lead to a higher quality educational experience, particularly in regards to youth developing positive beliefs about their science abilities.

4.3.3. Involve Youth in Any CCS Model and They Will Benefit

Regardless of the program model (contributory or co-created), participating in CCS excites and engages youth in science learning. Two key activities youth most commonly cited as sparking their interest in these projects were going outside and using scientific tools. There is a rich body of research detailing the benefits of outdoor learning [68–70]. The emphasis on enthusiasm for using science tools is consistent with previous research, which shows that access to tools is an important factor in developing youths' science self-efficacy [60,71]. Practitioners who may be lacking in resources to run a fully co-created CCS project with youth can still foster youths' enthusiasm and interest in science through a contributory program model.

5. Conclusions

We argue that the distribution of power over the scientific research process must be considered when designing youth-focused community and citizen science programs. We demonstrated here that when youth have more power in CCS projects aligned with community priorities, they have greater confidence in their abilities to do science. This has potential implications for whether and how youth might eventually choose to use science as a tool for action in their communities. Regardless of the program model, participating in CCS projects excites and engages youth in science learning. We hope these findings will be a good resource for educators, researchers, and CCS practitioners planning to foster science learning and work towards sustainable development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15118876/s1, Survey S1: *Winterberry* Pre and Post Youth Survey; Survey S2: *Fresh Eyes on Ice* Pre-Post Youth Survey; Protocol S1: *Winterberry* Post Youth Interview Protocol; Protocol S2: *Fresh Eyes on Ice* Post Youth Interview Protocol.

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Informed Consent Statement: Informed consent and parent or legal guardian consent was obtained from all subjects involved in the study.

Data Availability Statement: Sharing of youth data is prohibited under our IRB due to the potentially identifiable information in our very small communities in Alaska, from which most of the participants came.

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