# Science Identity and Agency in Community and Citizen Science: Evidence & Potential

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## Introduction

In recent years, there has been an explosion of interest in and opportunities for crowd-enabled and participatory community and citizen science (CCS) initiatives worldwide (Bonney et al. 2014; Theobald et al. 2013). With this interest has come a growing body of research about ways participation in CSS might support science learning for adults and youth (Bonney et al. 2015; Ballard et al. 2017; Brossard, Lewenstein & Bonney, 2005; Bonney et al. 2009; Houseal et al. 2014; Wals et al. 2014). In this paper, we synthesize the potential and evidence for science learning through CCS from a perspective of identity and agency.

There are a wide variety of terms and ways people can be involved. In this paper, we define CCS as activities in which members of the public collaborate with professional scientists to conduct scientific investigations, engage in monitoring activities, collect data, interpret results, and disseminate findings, producing *new knowledge* used for resource management or basic research (Ballard, Dixon et al. 2017). CCS often include participants collecting scientific data, but may also include designing the research question and methods, data analysis and interpretation, and/or disseminating conclusions to research and decision-maker audiences (Bonney et al., 2014; Shirk et al 2012). We explicitly include "community science", as well as the more recognizable (but often problematic) term "citizen science" to acknowledge the importance of community-based approaches and the range of ways professional scientists and the public can collaborate.

What does participation in community and citizen science science look like? For our purposes of looking at science learning and identity, we focus on the wide range of social interactions and settings, the range of tools people use, the range of roles people can take on, and the range of activities and practices that can span authentic science - from gathering data, to posing questions to dissemination. Participation could be classifying photos on a computer or phone, analyzing water or air quality or identifying birds as you hike. While some people participate alone, others do so with their parents or children, with a group of friends, or in their classrooms. They study places as close as their neighborhoods, backyards and even bellybuttons and as distant as far away galaxies and alpine ecosystems. Projects in places like urban creek, county beaches, and school gardens can give participants a chance to see a familiar place in a new

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light. Importantly, activities in CCS also often involve complex scientific reasoning, where 4th graders must argue with classmates to defend their bird identification, or a watershed group compares their own data to local, national, or global data sets. Some projects only ask participants to do one of these things, while and others encourage participants to do many. In addition to the research activities, some projects connect research to ongoing work like habitat restoration, community planning, or political advocacy.

Much of the research we draw on in this review has developed from sociocultural perspectives on learning (J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), activity theory (Eisenhart et al., 1996; Engestrom and Sannino 2010; Roth & Lee, 2004), and critical scholarship (Calabrese-Barton & Roth, 2004; Basu, Calabrese-Barton, Clairmont, & Locke, 2009). These perspectives examine ways in which social and cultural processes of learning are entwined with affective and cognitive processes, and how issues of equity, at play at macro and micro levels of activity, influence people's learning and trajectories. Learning is tied to the particular situations in which it occurs and can be best understood through "changes in participation" (J. S. Brown et al., 1989; Nasir, 2005; Rogoff, 1995)s. Issues of identity and community are addressed alongside the uptake of scientific concepts and tools. These perspectives are important to research and theory concerning CCS, especially for participants who are unfamiliar with - or who are from groups that have been historically marginalized from -- the culture of science and science education. CCS involves people in communities that stretch beyond the particular educational settings, in big ways or small, and so our understandings and investigations of it must consider those communities. At it best, CCS presents an opportunity to challenge the culture of science, and leverage and transform its tools to address the questions and concerns of broader array of people and communities.

# Why think about science learning through a lens of identity and agency?

**Learning as participation in cultural worlds**

Rather than independent from setting, learning is situated in ongoing activity and the particular contexts in which learners are acting. Learning relies on interactions with people, tools and objects, and with places (Lave and Wenger 1991, Rogoff 1995), and can see how someone's participation in a place, community or disciplinary practice changes (Lave and Wenger 1991, Rogoff 1995, Nasir 22005). In order to pursue trajectories into and through science, people - young and old - must learn not only concepts and skills, but must become versed in the norms, values, beliefs, expectations, discourses, and cultural processes of scientific communities (Aikenhead 1996; Lemke 1990). This makes participation in authentic science a powerful context for learning. Studies have shown that working within and contributing to communities (Rogoff 2014) also allows young people to learn norms, habits of mind, and dispositions that make science a powerful tool for understanding their world. In CCS, people inquire and act on both the physical and social worlds around them. They gain first-hand experience with tools and practices of science and can come to see themselves as community resources, build linkages between the academic, disciplinary, and everyday communities they inhabit (i.e. Rahm 2010, Roth and Lee 2004).

## Examining identity with respect to science

Recent educational standards promote science learning that emphasizes *doing*, and not just *knowing*, science (NGSS Lead States 2013). This kind of learning requires that we consider the identities and cultural backgrounds and experiences that learners bring with them (Gutierrez and Rogoff 2003). Identity is a powerful lens when designing for science learning, not just for students in schools, but for young people and adults in every life stage, and in any formal or informal learning setting. Looking at identity can provide insight into how people bring in and leverage personal resources, change in important or lasting ways relative to science practice, and develop agency to act in their lives and communities. Identity with science impacts what you decide to take up, how you interact with the world, how you approach problems, people, school, jobs, family, friends with respect to science. In fact, a variety of terms are used in this field, including *"scientific identity," "science learner identity," "identity related to science", "identity as a science learner," "identification with the scientific enterprise" - all of which are used interchangeably by the National Research Council (2009).* We here refer to identity with respect to science, or use the term used by the respective authors when referring to their work.

Broadly, identity with respect to science is about whether you see yourself and are recognized by others as someone who understands, uses, and does science (i.e. Gee, 2000; Carlone and Johnson, 2007; Bell et al., 2009). Science is a cultural world - distinct from many young people's family or peer group culture - that involves distinct norms, values, beliefs, expectations, conventional actions, and discourses that are shared by a community of scientists. Learning science, then is a process of meaningful engagement over time with practices of a community. Within this community, people must construct identities of who they are in relation to others in science, and who they want to be.

Researchers conceptualize of and study identity with respect to science very differently depending on their disciplinary grounding and approach. In one approach, researchers look at science identity narrowly, in terms of whether someone identifies as "a scientist", whether adults (Robnett et al. 2015, Chemers et al. 2011) or youth (Archer et al. 2010, Williams et al. 2014). This approach was early on questioned by Moje et al. (2007) as to how important it is for students to take on a "scientist" identity, as opposed to attending to whether people they see themselves as engaging in science or scientific practices, echoed as well by Carlone et al. (2008). While the former approach to identity with science has been important to including social and emotional aspects in popular conceptions of science learning - and has helped better understand student trajectories into science, it has several shortcomings. In particular, a narrow perspective of science identity does not account for (1) the degree to which identities are formed through interaction and through the stories people tell about themselves, (2) ways in which identities are situated and enacted when doing things, with people, and change when someone is doing different things, with other people, and (3) ways in which conventional descriptions of what it means to identify with science serve to marginalize some groups, constrict ways of being in science and purposes for science, and reinforce status quo power relations. There are many aspects of science identity, a wide variety of ways people identify with science, scientific practice and communities, and many kinds of people who use science, many purposes for using its tools, and many ways of being in scientific communities (Carlone & Johnson 2007).

We here draw primarily from two ways of conceptualizing identity, narrative identities, and identities-in-practice. This approach looks beyond the career pipeline to consider ways that youth might take up science for themselves (Nasir and Hand 2008, Calabrese Barton and Tan 2010, Basu and Calabrese Barton 2010). Some researchers examine identity by examinin*g narrative identiti*es, or stories people tell about themselves, and who they want to be, as well as stories other people tell about them (Sfard and Prusak, 2005). This foregrounds how one views themselves within a given context through their own self-narrative and their narratives about others. Some conceptions of identity emphasize personal beliefs and attitudes, for example, measured the degree to which participants endorse such statements as “I have a good feeling toward science” or “I could be a good scientist” (Roth and Li, 2005; Weinburgh and Steele, 2000). Carlone and Johnson (2007) present a useful framework . Based on a study of adult women scientists of color who described their pathways through school and science as a career, they identified three aspects of science identity: competence (demonstrating content knowledge and motivation to understand the world scientifically), performance (making visible to others one’s skills and fluency in the practices of science), and recognition (recognizing in yourself and being recognized by others as a “science person”. They found that by hearing womens’ narratives about their own reflections on their pathways through science,

Other researchers focus on *identities-in-practice*. Identities do not show up in the same way across all settings. A person may have many ways of identifying in relation to science based on who she is around and what she is trying to accomplish. We cannot assume that identities are static across classroom, home and community. An “identities-in-practice” perspective examines the identities people enact when they’re doing science and how *where* and *with whom* it is being done might influence how young people can act and identify (Tan & Calabrese Barton 2008). By looking at what kinds of resources for expression, contribution, and are available and legitimized in a setting (Nasir & Hand 2008), this perspective on identity allows attention to be paid to power and hierarchy within settings. (Nasir & Cooks, 2009, Nasir & Hand 2008). It asks how are identities assembled or configured through interaction, taking and leaving cultural practices and markers from science disciplines, immediate situation, and outside communities. An identities-in-practice perspective helps us recognize the many ways that people author their identities and place in science. This is especially important when thinking about adult as well as youth learning in science. Some argue that CCS - often done by free choice, and with possibility of using science for own community, own goals - presents a chance for democratization and disruption of science that could purposely lead away from conventional conceptions of science and science identity. Attention to the how and why identities form *in the moment* are important to understanding agency in science - where student exercise agency to take up or adapt, or where they may be exercising agency by rejecting or adapting particular aspects of science.

*Ages and Stages* - Research on youth identity and adult identity come from different traditions and methodological approaches, and also differs in the research questions that have been asked. Research on young people’s identity with science, on one hand, tends to focus on the trajectories of youth into science, into college studies and careers in science and the “STEM pipeline” (National Research Council 2011). This focus on the ways youth identify with science is important, but many scholars additionally focus on how youth develop identities with science in their everyday lives, with families and friends, and how this might influence who they are and who they are want to become, not just what career they will choose (Calabrese Barton and Tan 2008) Some of what we know about identities with science come from studies of adults (Carlone and Johnson 2007, Azevedo 2013). But even with these, questions about how identity translates in adult trajectories and the impact on longer-term identities or activity in other settings remain unclear. In fact, research on science identity with adults is often focused on college students, focused on identities with respect to study STEM or STEM careers (i.e. Robnett et al. 2013, Chemers et al. 2011), how identities with science might influence the STEM career “pipeline”, without examining the ways identities with science might play out in other parts of their lives, in the context of communities rather than school. For example, Eagan et al. (2013) studied whether and how undergraduate research opportunities helped develop students’ of color science identities, and the relationship to their intentions to pursue graduate or professional program in STEM. They found undergraduate research did moderately increase participants intentions to further pursue STEM work, and that this may have been because faculty mentorship helped them see themselves as scientists and perform as scientists.

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*Gender, Race and Class Intersectional Identities* - Examining identity is particularly important when considering non-dominant youth, as youth of color, low socioeconomic status, and young women often don't see science as a discipline for them or as relevant to who they hope to become because many science fields remain largely White and/or male (Archer et al., 2010; Brickhouse, Lowery, & Schultz, 2000). Science learning settings frequently do not leverage, and often marginalize, cultural knowledge that young people bring into the classroom (Calabrese Barton et al., 2012). When young people do express strong identities of who they want to be in relation to science, they are not always able to enact these identities in school because content-focused classrooms limit opportunities for young people to enact new ways of being in science (Tan, Calabrese Barton, Kang, & O'Neill, 2013).

While this research demands that we pay attention to how resources for identity construction are made available or restricted in different ways due to race, class or gender, studies, and how stories told by and about participants in CCS may reflect macro-level narratives, often to the detriment of learner agency. We must also be aware of how issues of race, class and gender intersect to put participants in a "double bind" (Ong et al. 2011) that can make navigating science and science education especially difficult.

With respect to gender, research on science identity and gender for young women specifically call out how the gender of adults around them doing science, for example science teachers, can greatly influence whether a young woman sees herself as using or doing science, and also depends on whether they see the values of science as compatible with their own values (Gilmartin et al. 2007). Brickhouse and Porter (2001) examined two young women of color in an urban school setting and found that feeling excluded from the school science community, due to a number of intersectional identities, can influence whether a young woman sees herself as capable of doing and becoming with respect to science. Carlone and Johnson (2007) examined adult scientist women of color and found that recognition from others particularly influence the trajectories of women of color in their professional careers in science.

## Learning as agency

Equity-minded scholars have critiqued research on identity and "communities of practice" for insufficiently addressing power dynamics embedded in science learning. They have proposed the construct of *agency* as a way to think critically about science learning and identity work in the context of a social structure (Calabrese Barton & Tan, 2010;). Though people have a say in who they want to become, individuals' agency can be limited by historical, social institutional, or local structures, and entwined with issues of race, class, gender and authority (Holland et al. 1998). In these situations, people must gain the power to resist structures or must "improvise". The concept of agency looks for moment of improvisation, resistance, and and self-determination, allowing us to consider how individuals take actions in response to specific situations or environments to change their position in a cultural world (Holland et al., 1998;). Where a "communities of practice" perspective helps us understand how involvement in scientific systems and cultures structures opportunities and constraints for learning, the concept of agency is needed to see how youth find their own way through and reshape these systems (Calabrese Barton & Tan, 2010; Carlone et al., 2014; Cobb & Hodge, 2011). For example, Holland et al. (1998) describe a low caste Nepalese woman who climbs the outside of a house to meet a researcher on the second-floor balcony. Social structures dictate that she should not pass through the house of someone of higher social status, but her improvisation suggests a moment of agency while remaining within the social norms.

Identifying moments of agency is critical to understand how pathways through science learning become meaningful to people, young and old. However, in order to see where agency is validated and

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supported, or constrained and denied, the science education research community needs to better operationalize agency (Arnold and Clarke 2014). We define agency as the capacity of individuals or groups to act upon, modify, and give significance to the world in purposeful ways, with the aim of transforming themselves and/or impacting the conditions of their lives within existing social structures (Holland et al. 1998). Basu and Calabrese-Barton's (2009) notion of *critical science agency* stems from this definition of agency, and is a construct we find to be most salient for thinking about science learning through participation in CCS. Their ethnographic research on critical science agency points to a need for new paths into, and through, science, especially for young people from historically marginalized communities, to rely on science subject-matter knowledge to make change, and to leverage their own science expertise "to reflect and act on injustice in their lives" (Basu and Calabrese-Barton 2009, 2010).

## Environmental Science Agency

We need to understand how people use science to *act* on the world around them, using the tools and practices of science, and how they come to see themselves (or not) as community resources, building links between scientific and everyday identities. The construct of Environmental Science Agency (ESA), adapted from Basu and Calabrese Barton's concept of critical science agency (2009), is a particularly fruitful lens through which to examine science identity and agency in citizen science, not only for youth, but potentially for adults as well. Environmental science agency (ESA) is the ability to use experiences in environmental science to make positive changes in one's life, landscape and community. ESA includes *learning science while doing science*, which can be a way to foster environmental stewardship, civic participation and meaningful science learning.

The three components of ESA, which are adapted from the three components of critical science agency offered by Basu and Calabrese-Barton (2009), are focused on participants'...:

1. *...Understanding of environmental science content, norms, and practices*. In the context of CCS, we look for participants taking up the "processes, skills and modes of inquiry associated with this content" (Basu and Barton 2010), in this case environmental science content, and their engagement with values and norms of science.
2. *...Building and identifying areas of their own expertise associated with environmental science*. In the context of CCS, we look for how participants develop particular roles within their project groups and environmental science more generally, and how people come to specialize (or not) in different parts of the scientific work.
3. *...Use environmental science expertise and CCS practices as a foundation for change.* Examine how people make use of science and the CCS project work to shift positions or identities that extend <u>beyond</u> project work, understand the everyday world in and formulate personal ambitions and goals in new ways, and most importantly, take actions to envision and direct the world in personally consequential and environmentally sustainable ways.

ESA incorporates theories of youth agency that emphasize that gaining power and agency in one's life (citation?), and in our communities, requires both individual and collective action with and through environmental science. Embodying this idea, young people participating in CCS projects that tackle environmental science questions locally and globally take responsibility for small parts of larger scientific efforts. Therefore, when examining CCS participation, we ask, how is science being put to use by participants, relative to their interests, their social worlds – how are consequential learning opportunities in science coming about? Focusing on ESA can help educators bridge inequities and encourage people to carve out places in science for personal and community interests.

# Why might CCS be a rich context for the development of identity and agency with science?

Participation in citizen science projects has great potential to foster development of identity and agency with science. An NRC (2009) synthesis of informal science learning research describes a clear connection between participation in authentic science experiences, learning and identity development, claiming that CCS encourages participants to "[t]hink about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science." (NRC, 2009, p. ES3). Particularly for adults, CCS might offer a way for those who don't identify with science, professionally or otherwise, to see it as a tool to address issues they care about, such as conservation and environmental justice issues; it also might offer a way for those who already identify with science to engage in practices linked to this identity, to continue to pursue activities that reinforce that identity. Importantly, for adults and youth, we need to consider not only those who do identify with science, but also people who do not identify with science, why that might be, and also how CCS might allow groups who don't traditionally identify with science to initiate projects and effectively ask scientists to come into their own community's space. This means not just looking at how barriers to identifying with science can be reduced through participation in CCS, but also consider the backgrounds and experiences of the participants (Dawson 2014), and the science knowledge and practice that they identify as valuable (Basu and Barton 2010).

### "Real" Science

In fact, CCS may be an ideal context in which to examine identity and agency with science because it provides a real practice, a collective project or endeavor that participants are *doing*, through which participants can develop roles and agency. The notion of "real" or "authentic" science is complex when considering CCS because it raises questions of what authenticity means and to whom (Rahm 2003). Who gets to determine what is authentic - scientists, youth, public participants, or educators? We think it is possible for multiple forms of authenticity to emerge. One important form is authentic contribution to institutional science - the data or knowledge generated. Often discussions of authentic science refer to the data or knowledge generated that is used for basic research, or monitoring that contributes to management and decision-making (Bonney et al. 2014), which others refer to as "static" authenticity or the "scientists' science" (Rahm 2003). Yet It is also important for people to develop ownership of the work and connection to their personal or community life, which may or may not come from seeing themselves as a part of "scientists' science" (Rahm 2003). CCS can be authentic in ways that emerge in a relationship between participant activities and the social and ecological systems in which they act. For example, a student's work may be authentic to their school or local community's concerns about air quality in the yard. In the discussion below, we focus on the authenticity of participants contribution to science, but look for other places that CCS allows participants to develop their own sense of authenticity, ownership and action in their CCS work.

### Tools, scientists and practices

Many CCS programs have characteristics of effective science learning environments. These include work with scientific tools, interacting with scientists and science mentors, opportunities to practice argumentation, inquiry and scientific communication. Participants can experiment with new roles, which allows for new ways of seeing themselves and being recognized by others (Holland et al. 1998, Carlone and Johnson 2007, Nasir and Hand 2008) and new narratives about who they are in relation to science

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and scientific communities. When CCS activity involves sharing scientific work with outside audiences – such as scientists, family members, peers, or the general public – youth participants may start to see themselves and be seen by others as community science experts (Calabrese Barton and Tan 2010). CCS can support both narrative and practice-linked identities. When CCS work involves collaboration with scientists, youth participants may develop new understandings of scientific communities and envision possible selves in science. Finally, when CCS scientific work results in local community action, participants might envision how science is useful in their daily lives and develop new narratives about science and themselves (Stepenuck and Green 2015).

While some of these characteristics are common to hands-on, inquiry- or project-based approaches to science, we find CCS is unique in the ways it can support science learning by (1) linking participant learning to meaningful products that are shared with audiences, (2) situating activity within professional, local, or interest-based communities, and (3) creating hybrid spaces with room for identities and preferences rooted in community and individual histories, as well as opportunities to take up the tools, practices and norms of professional science. This means that in addition to the notion of authenticity and authentic participation discussed above, citizen science involves participants in another key process that make it potentially unique for science learning and identity development, the notion of *production* . In using the term *production* we mean to focus attention to processes by which people create things that are shared with and used by others. Production may be of physical objects, or of knowledge and ideas. Products relevant to CCS include data, analyses, and graphical representation that are used for continued collaboration and reasoning. Products might be shared with researchers, managers, or local decision makers, as well as peers, school administrations, neighbors and family members. The value of production comes from seeing "a little bit of me in the world": "ideas need to be taken up by others. This is how learners can appropriate them and learn from the ways in which others use their ideas" (Okita & Schwartz, 2013). We draw from accounts of production as "knowledge creation" that stress the benefits putting learners' ideas "out-in-the-world" and emphasize that the act of producing, not just consuming, knowledge is a vital 21st century capability (J. S. Brown, 1999; Zhang, Scardamalia, Reeve, & Messina, 2009) critical to achieving "higher order" thinking skills (Gee, 2011).

Because CCS work responds to specific scientific or local needs, project topics and protocols can vary greatly. This means that narrowly defining learning outcomes relevant across a wide range of projects is difficult and inevitably leaves out important concerns and communities. Therefore, we need to understand processes that underlie positive learning outcomes. Attention to processes involved in production and authentic participation can help researchers and educators understand ways in which science learning can lead to civic participation and long-term involvement with science.

# Developing science identity and agency in citizen science: evidence and design

There is a growing body of research about the conditions and settings in which science identity and agency seem to be fostered by participation in citizen science. This work is beginning to reveal not only insights about citizen science as an approach to science learning, but also insights into the debates about definitions of science identity and the ways to study this construct. We discuss this evidence then draw from it to propose principles for the design of citizen science programs and offer implementation approaches that foster the development of science identity and agency among learners across a range of experiences and backgrounds.

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## Evidence of developing identity with respect to science for adults in the context of citizen science

There is very little evidence published on how citizen science participation influences participants' identity with science, for adults or youth, despite many conjectures and theoretical propositions that this should occur. Empirical research on participants' motivations with respect to science is much more prevalent, possibly because of the incentives by many programs to investigate recruitment and retention of citizen science participants (West and Pateman 2016). Jollymore et al. (2017) investigated the ways that participant motivations and other factors influenced data quality for several citizen-led water quality monitoring groups and found that what they called "social identity", seemingly a surrogate for motivations to participate, impacted the selection of sampling sites and data collection for different groups. Jackson et al. (2015) applied a "community of practice" lens to examine identity shifts for participants in an online crowd-sourcing project, Zooniverse Planet Hunters, and found that participants did move from peripheral to central members of the project community through participation. Though limited, these findings indicate that identity is an important component of participation in a variety of models of citizen and community science, from wide-scale crowdsourcing to community-led place-based project. A number of ongoing research projects are investigating in more depth, or across multiple projects, how participation in citizen science might influence the development of identity with respect to science, including a study of participants in the Coastal Observation and Seabird Survey Team (COASST) project (Parrish et al. in review), and a longitudinal study of science identity development for participants in six different citizen science projects across the U.S. (Ballard et al. in prep).

This scant research evidence has thus far only examined one project at a time, leaving open questions about how research instruments might vary across studies, and whether findings are applicable beyond the particular project. We describe here one recent longitudinal study of participants' identity development influenced by participation in citizen science that addresses this gap by looking across a range of six very different projects. We use this to illustrate a methodological approach to examining narrative identity across different citizen science projects, and the influence of participation intensity on multiple aspects of identity.

As part of a larger study examining science engagement, learning, and identity through participation in citizen science, Ballard et al. (in prep) conducted annual phone interviews over 4 years with nearly 40 participants across six different citizen science projects to investigate how participation activities and identities with respect to science changed over time. These projects spanned environmental and conservation foci (birds, Monarchs, water quality, air quality, migratory eels, and precipitation). Participants were purposively sampled across a range of engagement levels, where some participated consistently but at the minimum level of data collection, and others were trainers or leaders and volunteered intensively for the project. During interviews, participants were asked to explain in detail their activities as part of participating in the project, how they saw themselves in relation to the science, how other saw them, if they saw themselves as part of the scientific community, and if any of those things changed as a result of participation in the project, in their view.

Ballard et al. (in prep) found that far from identifying "as scientists", participants described a wide variety of aspects of identity they felt in relation to science. They found that a majority of participants felt strongly that they are someone who uses and does science and is recognized by others as doing so, regardless of engagement level. However, those who intensively engaged described many more diverse aspects of science identity, including contributing to science, and being part of the science community.

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Though participants in the more community-driven projects were more likely to describe a strong increase in these over time. Whether a participant had a previous formal background in science also strongly influenced identity development: those with very little science background often developed a more diverse or stronger identity with science over time, and those with a previous background in science often described how participation in the project reinforced their sense of being someone who uses and does science, contributes to science, is part of the science community. These findings are aligned with what we know about identities-in-practice (Nasir and Hand 2008, Calabrese Barton and Tan 2008): participant described ways the citizen science projects gave them opportunities to engage in and recapture science practices and ways of thinking that were important to their participation in local and scientific communities. However, it also indicates that identity shifts in adults may look different than those with youth: where youth identities with respect to science may get *transformed* over the course of participation in CCS (eg. from someone who doesn't see themselves as someone who does science to someone who does science when it involves friends, or when it serves a community purpose), with adults, for whom identities may be more settled or stable across settings, it may be more appropriate to think about how identities can be *connected* or expanded, linked to new communities or activities.

## Research and Practice - Key considerations for design of citizen science programs for <u>adults</u>

Additional findings from Ballard et al. (in prep) offer some key considerations for design of citizen science projects for development of identity with science:

**Identify and support project work as part of the science community** - First, a majority of participants described feeling they were someone who understands, does or uses science, and is recognized by others as doing so, regardless of project participation - so participation in citizen science serves to reinforce an existing identity with science to some extent. However, a majority of participants across projects said they felt like part of the science community <u>because</u> of their project participation, and this wasn't true previously or in their everyday lives. This means that citizen science participation may be particularly effective at supporting identities with science as a community of practice and a sense of social affinity with science.

**Provide opportunities to take on differing and additional roles in the project** - Ballard et al. (in prep) found that participants who were able to take on additional roles in the science process in the project described a stronger and more varied identity with science; this has implications for design of projects, where providing varied opportunities to take on different roles in the project could support participants' development of their identity with science. Examples are participants taking on the role of trainer or educator for new participants, developing alternative methods or techniques for data collection, or communicating with outside audiences like local government or schools.

**Communicate often and clearly about how project data is being used for science**- Crucial for design of citizen science projects, many participants explained that whether or not they identified as part of the science community depended on whether they were informed regularly about how their data contributions were being put to use by the project leaders and scientists. This took the form of newsletters or blogs, emails about new publications or environmental decisions that utilized the data contributed by participants, scientific research questions being investigated by project scientists, stories about fellow project participants.

**Acknowledge and draw on participants' local knowledge and expertise** - Not only did Ballard et al. (in prep) found that participants with a formal science background were reinforced in the ways they identified with science, many of these participants reported contributing their expertise in additional ways beyond the standard project activities. But in addition, many participants who did not have a formal science background prior to project participation described how they joined the project for other reasons, often a conservation or public health concern, bringing their facilitation, community organizing, outreach and training skills to the project, and with time began to identify with science in new ways. Projects that welcome and make use of broad "non-science" experiences and expertise provide multiple entry points for participants to shape their own learning through the project, allowing multiple paths for people to identify with the science that is relevant to them.

## Evidence of development of identity with respect to science for youth in the context of citizen science

While more research has explored CCS learning outcomes for young people such as science content, practice, and changes in perceptions of scientists (Houseal et al. 2014), there is a small but growing evidence base for how CCS can be a context for youth identity work and agency. Two recent ethnographic studies investigated youth identity and agency in the context of a collaborative CCS project where high school youth from non-dominant communities worked with scientists to participate in herpetology monitoring and field ecology. Huffling (2015) found that youth agency was enabled when young people had opportunities to investigate issues in their community, were able to participate in decision making, and had repeated opportunities to participate in field ecology practices to ensure success. Carlone et al (2015) found that fear of the outdoors, amphibians, and reptiles, in small doses and when handled with empathy, encouraged youth with limited previous experience outdoors to push their comfort zones and engage in identity boundary work. Researchers found that a number of factors were important to working through fears: boundary objects, flexible use of time and space, social support, and anecdotal scientific anecdotal knowledge . These two studies suggest that CCS can be a rich context for youth agency and identity when it is collaborative, place-based, and attends to who young people are. While they do not argue against engaging youth in issues of local or immediate concern, Carlone et al. (2015) caution against circumscribing the futures and identities young people might envision. They challenge the field to "encourage youth to participant in new communities of practice, engaging in identity work previously unfamiliar to unusual for them."

Though these studies suggest that CCS can be a context for science identity work, using a quantitative identity construct, Williams (2017) found that participation in a citizen science project actually had a slightly negative impact on science identity. This existing research suggests that there is more to explore in terms of how we conceptualize identity and agency and how CCS might foster it. While we've not found published evidence for science identity development as a function of citizen science participation as influencing youth intentions or college and career choices in STEM, we have observed several cases where involvement in a CCS project seemed to motivate and support continued engagement in science learning.

## Environmental Science Agency for youth participating in community and citizen science

We investigated CCS as a context for youth development of ESA (Ballard et al 2017) in 10 case studies of youth-focused CCS programs for youth ages 8-18. Using a case study design (Yin, 2013),we collected observational field notes, reviewed program and student-produced artifacts (Bowen 2009), conducted semi-structured interviews (Patton, 2002) with 6-10 focal youth participants and educators before and after their CCS experiences. Case studies ranges from in-school and out-of-school; long-term (more than 2 months) to short term (one day); projects on-site at school grounds to field trips; and a range of topical/ taxa foci (water quality, bird, sand crab, ladybug, plant phenology, air balloon mapping, etc). We compiled profiles of focal youth participants and drew our analysis of individual ESA trajectories from these profiles. These cases provided a close-up look at the kinds of interaction, learning and individual work that took place during CCS experiences. Drawn from initial 5 cases studies with middle and high school aged youth involved in medium- to long-term CCS projects, the findings below suggest that CCS can be a promising context for youth development of ESA (Ballard et al. 2017). Early analysis of an additional 5 case studies has strengthened these findings, while also suggesting additional factors in identity and agency development for CCS that involves younger students, online components, residential schools, and short-term events.

**Understanding environmental science content and practice**: In the case studies we observed young people developed understanding of environmental science content and scientific inquiry in broad range of ways (Ballard et al. 2017). For example, one eighth grader, Emma, who participated in a water quality monitoring and restoration project, learned water quality monitoring techniques, developed understandings of native species restoration, and developed efficient methods for sampling and testing water. In other projects, youth came to understand the techniques of ecological field methods, and norms of science writing or presentations at professional scientific meetings.

**Identification of specialized roles and expertise.** Though some youth did not identify an area in which they took on a specialized role (this was more common in school-based project than out of school), many youth did. Roles came about through a number of processes, including as a result of collective need, personal initiative or educator facilitation. In some cases, youth roles proceeded directly out of new environmental science learning -- such as taking a lead role in analyzing a data base. In other cases, youth described ways in which these roles connected to and expanded identities they were building outside the project - for example, as good writers, as peer leaders, or abstract thinkers -- and these identities then led them to further environmental science learning (Ballard et al. 2017). In the water monitoring project, Emma came to specialize in water quality monitoring. She took the lead in facilitating water monitoring with her peers because she was always on time. As she gained experience, she learning more about scientific data collection and explained the monitoring techniques to scientists while she and her peers presented findings at a scientific conference.

**Using science and their CCS experiences as a foundation to create change in their lives or communities.** This happened in small, discrete ways -- such as carrying a practice from CCS project to an interest-based extracurricular program, or to a school-based setting -- as well as in ways that seemed to reflect a change in perspective and behavior -- such as a young man starting to see local research as a way to address many issues in his community, from littering to police brutality (Ballard et al. 2017). In Emma's case, she began to teach new youth and adult volunteers, became more confident and willing to stand up for herself and "know who she is" at school and at home, and she joined an environmental justice summer program measuring air quality and presenting recommendations to local city agencies. For other youth, participation led to further pursuits in science, such as participation in environmental health studies of air quality, internships with local restoration group, selection of science classes at school, and pursuit of science majors at college. Development of identity and agency was supported by positioning youth as experts for both local advocacy communities and scientific communities, by apprenticeship in practices of science, and by relationship with program educations who could broker opportunities to continue science learning in other settings.

Though we have presented some grounding examples of the ways that the three components of ESA appeared in CCS sites we studied, youth trajectories were unique to individual, the social context, and the CCS project. We found evidence for some degree of environmental science agency for nearly all youth. However, only a subset of youth -- like Emma -- displayed evidence of all three aspects during our study.

### Key practices for youth that facilitated development of Environmental Science Agency

We identified three practices common among many of the youth participants which formed pathways of ESA development (Ballard et al. 2017, https://yccs.ucdavis.edu). We found that when youth are responsible for ensuring rigorous data quality, it positioned students as experts, and encouraged their investment in the scientific work. This involved developing an understanding about why we're engaged in the broader project, what constitutes high quality data for a given CCS project, and gradually releasing responsibility to young people to ensuring high quality data collection.

Our findings also suggested that when youth shared their science findings with outside audiences, they became motivated and took ownership of those findings. This involved youth sharing the results of their scientific work formally and informally with scientists, educators, other young people, local agencies, and members of the public. This may be explained by research showing that accountability to an outside audience increases young people's use of scientific language and norms (Heath 2000, Heath 2004, O'Neill 2001), breaks down the isolation of the classroom (Barron et al. 1998) and can encourage extra revision and organization of understanding (Okita & Schwartz, 2013). Presenting to an outside audience helps to position youth as community science experts (Barton and Tan 2010), making a visible and valued contribution to their communities.

Finally, youth engaging with complex social-ecological systems helped foster ESA. This practice involved young people observing, considering, and acting within the human *and* natural systems around them. YCCS work often asks young people to look closely, with new tools and new eyes, at nearby landscapes. This be an important way to help students understand that human activity makes up an integral part of ecological systems, with both positive and negative effects. This makes it easier to see the role that they, their neighbors, and their governments play in complex socio-ecological systems.
These youth practices motivated movement across the three aspects of ESA, linking expertise building to specialized roles within environmental science work. We do not propose linear development across the three aspects. Rather we saw that there were many starting points and that over time youth connected specialized roles to identities and communities outside the project, and came to use environmental science content and practice as resources for this identity work.

## Research and Practice - How can citizen science programs be designed to foster youth ESA development, and what practices can practitioners use to implement programs?

We offer considerations how to design and implement of YCCS programs for youth, drawing on our previous research (Ballard et al. 2017) and ongoing work with practitioners to support youth agency and identity work. The design of a CCS program does not necessarily reflect how a project is implemented, and we found that educators can play a strong mediating role in whether and how young people engage develop ESA (Harris 2017). These are difficult tensions that may arise for educators as they implement CCS projects. We identified three practices for implementation that educators can use to deepen learning and foster ESA during the course of YCCS activities, regardless of the particular project or program (Harris 2017).

**Incorporate multiple stakeholders for young people to engage with** - Outside stakeholders can play multiple roles; they can simply listen to young people, use the data or findings, provide feedback, share their knowledge, or make decisions based on what they've learned. Stakeholders can include scientists, policy-makers, community stakeholders and leaders, other CCS participants, and the general public. Audiences may be in-person or online. They may be anticipated by educators, such as a presentation at a scientific conference, or unanticipated, such as neighbors passing by during data collection.

**Draw on young people’s and community knowledge** - Drawing on young people’s funds of knowledge of their study site and communities (Calabrese Barton & Tan 2010) as well as learning studying the history of the study site can help young people see themselves and their role within the social ecological system. Creating opportunities to talk with community members about local places and gain community knowledge can connect learning to local action.

**Connect short-term activities to long-term learning -** When developing ESA, youth move from practices that most students in a project might learn (like how to use a transect tape measure), to focusing on more specialized roles that reflect individual interests. Rather than everyone having the same learning experiences, we suggest designing projects to encourage the highly varied ways that science and YCCS experiences can become meaningful to young people. This trajectory can help educators and project designers think about how short experiences and concrete practices of science might connect to longer term learning processes.

**Create feedback loops and multiple entry points** - For example, learning and developing a knack for using calipers and water testing kits led one student to take responsibility for data collection and analysis in her team or class. As a result, she learned more about principles of data quality and their importance for being able to make credible claims. Extending her work in the project, she then came to teach peers and adult volunteers how to collect and assess water samples, gaining leadership skills that her grandmother saw her put to use at home and in school. We suggest designing YCCS projects so they can provide multiple ways for young people to participate in the science process and decide what role they found most meaningful.

**Educators can work to position students as epistemic agents** and authors of investigation (Stroupe 2014 and Calabrese Barton and Tan 2010), which involves helping students take on meaningful roles during CCS projects. How educators frame CCS work and student roles - through their words and actions - can influence whether students see themselves as having important roles in authoring scientific work (Harris 2017 - dissertation; Russ and Luna 2013). Students can feel like automatons collecting data for scientists, which Moss et al. 1998 found to be a real risk. Though educators may be personally excited that student are contributing to scientific work, it is important for them to position young people as authors of investigations too.

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**Educators can frame the work globally and locally** -- simultaneously part of larger global scientific endeavors and as well as locally relevant issues relevant around the study site or community. Global contribution may be meaningful framing for a subset of young people who already identify with science, whereas other youth may find local investigation compelling. Framing the work as important for global contribution *and* understanding local ecosystems helps tap into interests that motivate a wide variety of students.

**Educators can attend to the unexpected**, by paying attention to surprises that emerge from the natural world or youth. CCS necessarily encounters unknowns, answering [[real]] questions about something in the world. It is important to incorporate these as well as emerging questions into instruction, allowing students to reason about data and reflect on their experiences, and incorporating them into instruction. CCS is unique because educators and youth don't know what will happen. Educators can capitalize on rich teachable moments and work with young people to figure out new understandings together.

## Further research needed focused on science identity and citizen science?

Though existing CCS research around identity and agency has addressed a wide range of settings, age groups, and issues, this is still only a small slice of common CCS experiences. We reviewed research that looked at experiences that last more than one day, participants ages 8-adult, environmental science projects, outcomes for individuals, contributory or collaborative activities for adult participants, and activities where participants collect data in the field as part of their CCS project. Yet this is a narrow look at the broad forms of CCS participation and kinds of CCS contexts. Based on gaps in the literature and limitations of findings from our research, we propose key questions for the field as we continue examining science identity and agency in the context of CCS participation.

| **Gaps and questions for future research in CCS** | |
|---|---|
| Time/ Duration of participation | |
| Short-term CCS experiences<br>(eg. day long bioblitzes, bird counts, first flush, king tide monitoring, site-specific projects at parks, environmental centers, public events.<br>Short term CCS experiences reach a high number of people, however, with fwere opportunities for relationship building, less time to build and extend roles and expertise within the project, these experiences may not provide the same kinds of pathways for identity and agency development. | What does ESA and identity work look like for <u>short</u> durations of participation?<br>How can short-term experiences with CCS be designed to encourage students to carry in and build on identities and existing knowledge about places, community and science?<br>How might short-term CCS experiences be aligned with school practices and communities? |
| Long-term CCS experiences<br>Examples include: science internships, long-term monitoring projects, summer and afterschool programs, year-long classroom | How do shifts in identity and agency within long-term CCS influence participation in communities beyond the project -- academic, local, peer, etc. -- including civic participation in the future? |

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| projects | |
| Kind of activities | |
| Online CCS experiences<br>Examples include iNaturalist, Zooinverse, online communities like Public Lab | What approaches foster agency and science identity work in online settings? What forms of identity work What might Key Practices for ESA - like taking ownership of data, interacting with the Social Ecological System, and sharing findings - look like in online spaces and designs?<br>How do online identities and agency with respect to CCS issue-areas (especially environmental issues) relate to offline identities and behaviors?<br>What roles and ways of personalizing or specializing participation are available in online projects? How might nature of participation change over time? |
| Community science and adult participation | What is the nature of agency and identity work when adult participants lead projects in collaboration with scientists?<br>How might changes in identity and agency foster resilience of social ecological systems and agency at collective or community wide level? |
| Classroom and school-wide projects | In what ways might CCS create a "third space" that opens room for identities, practices and forms of agency not as common in schools? In what ways does being situated in a school change students' perception of authenticity and opportunities for agency? |
| Participants | |
| Young participants | What does ESA look like for young participants, e.g. K-2?<br>How do young participants understand the institution of science and contribution? What forms of authenticity and aspects of experience are most impactful for young learners? |
| Disciplinary focus | |
| Content beyond environmental science | What does identity work and agency look like in other content areas like astronomy or biomedicine? What is the role of a disciplinary focus in relation to agency? |
| Community level outcomes | |

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| Community level outcomes | What about Community-level learning outcomes, particularly with respect to developing science agency? Methods and theory in natural resource sociology could be applied to conduct studies of social learning and action at the community scale, including methods around measuring social capital, community capacity, trust between the public, scientists and land managers, among others. |

In order to address some of these gaps, we are engaging in a several new studies that examine the range of contexts and structures of participation in CCS, as well as methodological approaches we think lend themselves particularly to examining identity and agency with respect to science, particular design-based research (Sandoval and Bell 2004). Design-based research not only promotes intense collaboration between researchers and practitioner educators and citizen science program managers, but also allows for development of learning theory through experimentation with intervention designs, in this case, design and implementation strategies for citizen science programs to support science learning. We are investigating ESA across a range of settings including short-term and online settings through a design-based research study of youth participation in CCS in natural history museums (https://education.ucdavis.edu/learn-citizen-science). We are also studying ways ESA might develop for adult participants in community-drive, community science projects in collaboration with Public Laboratory for Open Science and Technology (https://education.ucdavis.edu/ccs-public-lab).

# Conclusions and Challenges for the Field

Designing community and citizen science to promote development of identity and agency with science brings with it challenges for individual participants, scientists, and educators that are crucial to consider when we think about CCS as a context for learning. We offer final points and pose further questions about how to design CCS such that it can support science learning with respect to identity and agency. First, participants are not blank slates and bring with them diverse kinds of knowledge, expertise and identities with regards to science, place, and local communities, and we've seen that science identity and agency development involves a incorporating these myriad aspects of identity into the practice of the CCS project. So while scientist collaborators often focus on producing specific scientific knowledge with narrowly-defined protocols, finding ways to incorporate participants' existing local and traditional knowledge, social and cultural histories and identities as a part of the practice of the science, could better support their agency and identity development with science, as well as enhance the outcomes of the project. Second, one size does not fit all participants, and participation in CCS does not always lead to quality science learning. Individuals engage along their own trajectories, bringing who they are and who they want to be to scientific practice. Designing CCS to support multiple entry-points and multiple iterations of participation and role expansion would allow for more varied and stronger identity with science along their trajectories. Third, what is "authentic" varies for participants and scientists, but feeling like the work is real and meaningful is important for identity work. "Real" might be validated by contributing data that scientists will use in their scientific research for some participants, which is currently a common framing of what CCS work is about. However, others might see "real" as enabling people to engage with and take action locally in places they care about. Design of CCS to support participants to engage with place in critical ways, and link directly the science to stewardship and/or social change action explicitly, can allow people to see ways that their own agency with science can address issues they see as fundamental to who they are. For similar reasons, we've seen evidence that

CCS practitioners and scientists could foster science agency development by positioning participants as co-creators and disseminators of knowledge, and framing their projects in this way explicitly. How can CCS practitioners support deeper engagement in scientific practices and identity development? While some have argued that the tension can arise when trying to meet multiple goals for high quality science and high-quality learning experiences (Tinker 1997), we suggest that good science and good science learning are often interdependent. We found that especially for adults, science identity development is entirely intertwined with participants being aware of, understanding, and believing that the scientific knowledge and products participants generate in community and citizen science are valid, rigorous, and being actively used for scientific research and decision-making. This means that the dichotomy posed by many, that CCS designers must prioritize high quality science OR high-quality science learning, is a false one, and that high quality science learning vis a vis development of identity and agency with science depends on the science also being high quality.

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