6-9-2020

# STEM Identity Authoring: Intergenerational Collaborative Learning in Informal STEM Programs

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University of Connecticut, 2020

## Abstract

The problem this research addresses is the lack of opportunities for many people to develop positive identification with STEM fields (i.e., science, technology, engineering and math). This multiple case study will investigate STEM identity authoring in three intergenerational collaborative learning partnerships in an informal STEM program. Adults and high school teens were paired in two-day workshops to learn conservation science and geospatial technologies with the goal of designing and implementing community conservation projects and further developing their identification with STEM. This research examined how the design and implementation of intergenerational projects provided opportunities for: (1) adults and teens to demonstrate competence in STEM knowledge and understandings, (2) adults and teens to participate in the performances of STEM practices, and (3) adults and teens to be recognized for their competence in knowledge and performances of STEM fields. The study also examined how underlying social structures (e.g., race, gender, age, socioeconomic status) may have promoted or inhibited identification with STEM. Qualitative methods were used throughout. Data consisted of field observations of intergenerational teams followed by separate semi-structured interviews with each participant. Artifacts such as presentation posters, online maps and websites, educational materials (e.g., pamphlets and booklets) email and forum posts were used as secondary data sources. Findings inform how formal and informal STEM education programs can foster positive identification with STEM fields and lead to increased participation in STEM pursuits throughout the lifespan.

STEM Identity Authoring:

Intergenerational Collaborative Learning in Informal STEM Programs

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B.A. Boston University, 1983

M.A.T. Wayne State University, 1992

A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

at the

University of Connecticut

2020

APPROVAL PAGE

Doctor of Philosophy Dissertation

STEM Identity Authoring:

Intergenerational Collaborative Learning in Informal STEM Programs

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2020

## Acknowledgements

I would like to thank my major advisor, Todd Campbell, who first encouraged me to pursue a doctorate in science education and then spent countless hours guiding me as I navigated graduate school. Your endless patience and dedication to your students is a high bar I will strive to emulate in my own career as an education professor. I also want to thank my associate advisors, David Moss and Suzanne Wilson for your thoughtful guidance and encouragement throughout my graduate school journey. John Volin and Morgaen Donaldson, thank you for serving on my committee and offering your invaluable insights on my research and dissertation. I would also like to thank the professors in the education department for sharing with me your knowledge and commitment to education and supporting me as a scholar. Thank you to my research collaborators in the Department of Natural Resources who welcomed me as a partner in the project that is the foundation of this dissertation.

To my family and friends, I could not have persevered without your love and support. Thank you for all the check-ins, texts, phone calls, and even Facebook posts that encouraged and buoyed me when I felt overwhelmed. Most of all, to my husband and best friend, Orlando, you have been my rock, my partner in celebrations, and my shoulder to cry on. I am deeply grateful for your love and unwavering support.

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# Chapter 1: Introduction and Literature Review

Historically, only a fraction of our society has benefited from quality science education, both formal and informal (Herrenkohl & Bevan, 2017). Too many U.S. students become unenthusiastic towards science technology, engineering and math (STEM) fields during their school years missing opportunities for rewarding and well-paying careers, the development of STEM literacy that will guide them in personal decision making and problem solving, and the joy of discovery of the natural world. A high percentage of these students are women or from minoritized populations (National Science Board, 2018). In 2015, women comprised 50% of the U. S. college-educated workforce, but only 28% of the science and engineering jobs. They are severely underrepresented in engineering (15%), physical science (28%), and computer science (26%) occupations which account for more than 85% of STEM employment. Hispanics, African Americans, and Native American or Alaska Natives together make up 11% of workers in science and engineering occupations although they account for 27% of the adult population in the U.S. (National Science Board, 2018).

While advances have been made in closing the science achievement gap between White males and females, the gap has not narrowed for females from other ethnic groups. Yet, STEM occupations present opportunities for higher income, out-earning non-STEM fields by 12 – 30% at every education level. Between 2017 and 2027 STEM-related jobs are expected to grow by 13% while non-STEM jobs by 9% (Education Commission of the States, 2019). While there is no shortage in the academic STEM job market, there are shortages in government and government-related job sectors as well as in the private sector especially in computer science, physical science, and engineering (Xue & Larson, 2015). Many in the U.S. are concerned that the nation is even more at risk economically, than in 1983 when the report, *A Nation at Risk* was released (Kirwan, 2013). Perhaps more importantly than developing a STEM workforce is developing STEM literacy in all people that enable them to understand the major scientific issues of our times and how STEM fields can help to find solutions.

The problem this study addresses is that many people never form STEM identities through formal STEM learning environments that enable them to participate and contribute in STEM pursuits throughout their lifetimes. Initial interest and participation in science during the elementary grades declines for many students during the middle school years and does not bounce back in high school, even though achievement stays high (Christidou, 2011; Lindahl, 2007). Many learners - including members of underrepresented groups in science - who experience failure in school science, may demonstrate competence in the same subject matter in informal settings (McLaughlin, Irby, & Langman, 2001; NRC, 2009). Developing identification in science may contribute to students' abilities to persist in their formal and informal studies of STEM fields (Archer et al., 2010; Basu & Barton, 2007; Calabrese Barton et al., 2013; Carlone & Johnson, 2007; Stets, Brenner, Burke, & Serpe, 2017). For the purpose of this research, I will use STEM as denoting a broader field in which science is nested. While STEM identity authoring in youth has been studied in both formal and informal environments, the literature is mostly silent on informal collaborative intergenerational STEM learning and identity authoring. To make STEM fields more attractive to women and underrepresented minority groups so they will enter and remain in STEM professions, understanding the dynamics of authoring a STEM identity is crucial. Novel approaches such as intergenerational collaborative partnerships need to be examined to determine if they could be effective methods to promote STEM identification in underrepresented populations in STEM.

A STEM identity is a type of social identity where one develops an affinity towards a STEM field. Affinity identities are one type of identity. Gee (2000) describes multiple types of identities people have throughout their lifetimes that are foregrounded depending on differing social environments and continually changing as a social process: “The self is not a static entity, but a dynamic social process, that shapes and is shaped by the social encounter, a transformative process of being” (Varelas, Kane & Wylie, 2011 p. 828). Affinity identities are recognized by groups that share a common interest and develop a set of shared distinctive practices. Members are often more connected to the practices and experiences than to other group members. They connect to other people and sustain their membership through the practices (Gee, 2000). The following examples are from the first cohort of the informal learning program that is the context of this research. A teacher who was interested in birds began identifying birds in their backyard. She learned more about birds by connecting to other birders online and through her local Audubon group. She learned about different ways to identify birds, how to band birds, record and share information, and about the needs of migratory birds. Other birders recognized her as knowledgeable about birds and skilled at the practices associated with being a bird bander. As she learned more about birds, she also authored an identity as a birder, something that may continue throughout her lifetime.

Informal STEM learning (ISL) environments are places where people of all ages and backgrounds should have access to explore the many-faceted domains of science, technology, engineering and math, and develop their sense of agency and identification with these fields (NRC, 2009). While identification with STEM refers to an affinity with a STEM field (e.g., feeling you are a science kind of person and can understand, use and contribute to science), agency in STEM refers to the capacity to act independently, and make decisions and contributions in STEM pursuits. Our birder not only identifies with birding, but is able to contribute to the field by banding migratory birds not previously found in her area, recording data, and sharing that information with others - including her students through formal and informal STEM learning experiences.

Two major goals of most informal STEM programs are: 1) developing and nurturing STEM identities and, 2) increasing participation by historically underrepresented populations in STEM. A potential third goal is to promote STEM learning across the lifespan (NRC, 2009). Intergenerational collaborative learning may provide an opportunity to meet these goals. Intergenerational collaborative learning emphasizes collaboration between partners at different life stages that enhances the learning of both. This study is part of a larger funded intergenerational learning project that partners teens and adults from the same or nearby communities in two-day workshops to learn conservation science and geospatial technologies as they consider community land use projects they may want to pursue after the workshop. After the two-day workshop, the partners worked collaboratively to continue designing and then implementing community land use conservation projects over the course of a year.

The research question that guided this study is: How do intergenerational collaborative learning partnerships affect STEM identity authoring in teens and adults?

## Lifelong Learning and STEM Identity Authoring in Informal STEM Learning Programs

The following literature review of STEM identity authoring in informal STEM learning programs provides the context of my dissertation research. The review provides a background for understanding: (1) lifelong STEM learning in informal STEM settings, (2) features of informal STEM learning programs important to STEM identity authoring, (3) accessibility for learners from underrepresented populations in STEM, and (4) intergenerational learning in informal STEM learning environments. These are important components to understand how STEM identity authoring may occur in informal intergenerational STEM programs.

### Lifelong STEM Learning in Informal Settings

"Lifelong STEM Learning" is one goal set forth in the National Research Council (NRC) report on informal STEM learning. Lifelong learning refers to acquiring competencies and attitudes, and developing the ability to effectively use information throughout different life stages. The learning that takes place as people move through different social settings and activities is referred to as “life-wide learning,” in constrast to “life-deep learning,” which includes beliefs, ideologies, and values that are learned through participating in the community and broader culture (NRC, 2009). These three concepts merge in the diverse forms of informal STEM learning environments.

Learners’ needs change at different life stages, but all learners can continue to learn in environments that acknowledge their experiences and needs. Maturity develops increased memory capacity, reasoning, and metacognitive skills that allow adults to learn about science in different ways from children or adolescents. Adult STEM learners are motivated to learn about specific domains of science that relate to interests and problems of their everyday life and can develop expertise in those specific domains (NRC, 2009; Sachatello-Sawyer, 2006). Older adults have a lifetime of experiences and may have developed extensive background knowledge and skills. They can draw on these rich life histories to draw analogies to understand new concepts and develop new insights (NRC, 2009). Senior citizens may have certain challenges associated with aging such as declines in sensory capabilities, but the ability to reason, recall, and interpret events remain stable in most older adults.

Many factors are involved in the development of a lifelong STEM identity. While initial achievement and interest in science may be a factor in the early stages of STEM identity, they are not enough to develop a sustained identification with science (Carlone & Johnson, 2007) that allows students to persist in their formal and informal studies of STEM fields throughout their lifetime. Developing identities throughout one’s lifetime is in effect learning as it encompasses a transformation and change of persons (Lave & Wenger, 1991; Varelas et al., 2011).

**Features of ISL Environments Important to STEM Identity Authoring**

"[T]here are no learning environments or experiences that are neutral to identification, although some may have a more profound effect on youths' identification processes than others—in expansive or constricting ways" (Bell, Van Horne, & Cheng, 2017 p. 368). People learn science in a variety of contexts outside of educational institutions throughout their lifetimes (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Falk, 2001; Falk & Dierking, 2000) and most people without a degree in science learn more science knowledge in free-choice ISL environments (Falk & Dierking, 2013; Falk & Needham, 2013; NRC, 2009). Anderson (2007) argues that part of identity is learning the skills, concepts and practices of a community or enculturation through social participation. ISL environments provide opportunities for just such social participation within STEM fields (Dierking et al., 2003; Falk & Dierking, 2000; Falk & Storksdieck, 2005; NRC, 2009).

Since most participants choose to engage in ISL environments, they are characterized as being driven by the learners' needs and interests (Dierking et al., 2003). ISL environments are typified by experiences that are learner-motivated and guided, collaborative, and open-ended (Falk & Dierking, 2000; Griffin, 1998). ISL programs often prioritize increasing motivation and confidence among participants through a variety of features (Fields, 2007; Johnsen, 1954): (1) being located in novel environments, (2) participation in authentic science projects that foster curiosity and exploration, (3) using apprenticeship models, relying on inquiry-based, hands-on activities (Barab & Hay, 2001; Gibson & Chase, 2002; Markowitz, 2004; Sondergeld, Rop & Milner, 2008), and (4) providing access to resources (e.g., laboratory equipment, professional scientists, etc.) not typically found in formal school settings. All of which may influence the development of the participants' STEM identities (Barab & Hay, 2001; Markowitz, 2004; Robbins & Schoenfisch, 2005).

ISL environments should be designed to provide opportunities for intentional practice-linked identification (Bell, et al., 2017), as they provide additional or alternative spaces for the development of competence and performances which may help support the development and maintenance of STEM identities. Along with demonstrations of competence and performances, external and internal recognition of STEM competences and performances, and constraints of social structures - ranging from group norms to macro-structures of race - gender and class also affect development of a STEM identity. While girls have been found to have fewer opportunities to engage in the practices of science in formal science spaces (Alexander, Johnson, & Kelley, 2012; Hill, Corbett, & Rose, 2010; Jovanovic & King, 1998; Tan, Barton, Kang, & O'Neill, 2013), they have been found to develop science identities when engaged in informal spaces (Tan et al., 2013; Todd & Zvoch, 2017). ISL environments provide opportunities for youth to be part of positive mentoring relationships and have safe spaces to participate (Eccles & Gootman, 2002; Heath & McLaughlin, 1993), while allowing adults to demonstrate and share their competences and performances by teaching or mentoring, further reinforcing their own STEM identification. These may also be spaces where adults can learn new competences and performances from others including younger participants that further develop their STEM identities (Tempest, 2003).

**Accessibility of ISL Programs for Underrepresented Populations in STEM**

ISL programs offer a variety of entry points into STEM learning and have the potential to promote STEM identification in a variety of populations including those historically underserved in formal science education (e.g., Basu & Barton, 2007: Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013). While equal access is one of the goals of out-of-school science learning programs, research has shown that participation has been mostly those from advantaged groups (Dawson, 2014a, 2014b; Dawson, 2017; DeWitt & Archer, 2017; National Science Foundation, 2012;

Organisation for Economic Cooperations and Development, 2012). This population often comes to ISL programs with already well-developed interests. (Lipstein & Renninger, 2006; Renninger & Hidi, 2002; Renninger, Sansone, & Smith, 2004). Logistical (distance to workshop, transportation), financial (engagement in larger project impacts the amount of time for jobs), and cultural (feelings related to fitting in) barriers have been found to limit attendance to ISL spaces, such as museums and science centers, and may actually promote inequities in ISL programs (Dawson, 2017; Feinstein & Meshoulam, 2014). Dawson (2017) posits that ISL programs must go beyond opening the door for diverse learners to creating spaces that do not attempt to change the person to fit the program, but instead give learners the resources and power to shape those spaces and activities for their purposes.

To promote broad and inclusive participation in ISL programs, the NRC (2009) has determined that programs need to allow space for learners to use their unique backgrounds and experiences in engaging with ideas and practices that are familiar to non-scientists such as drawing analogies and asking questions. Scholars argue that programs should be developed through community-educator partnerships and if possible be grounded in real-world scientific problems and ideas that are relevant for the community. Input from the community to inform the entire process starts with designing goals. Informal as well as formal learning environments can cause marginalization harming participants' desire to learn or they can be transformed through a focus on positive disciplinary identification to be more inclusive, supportive, and equitable. It is crucial for these partnerships to be inclusive, sustained, and effective (Bell et al., 2017).

Studies of STEM identification in ISL environments have mostly focused on how these environments affect P-12th grade learners (Habig, Gupta, Levine & Adams, 2018; Pattison, Gontan, Ramos-Montanez & Moreno, 2018; Riedinger & Taylor, 2016; Ryu, Tuvilla & Wright, 2019). Consequently, an under-researched area relates to how these programs affect the STEM identification of adults involved in these ISL programs. Intergenerational collaborative STEM learning in informal spaces is an area that needs further exploration to determine best practices for how adults and youth can learn together and support each other's STEM identification.

**Intergenerational Learning in ISL Environments**

Many studies of intergenerational learning have been primarily concerned with knowledge transfer between novice and more experienced workers in organizational studies in workplaces (Bailey, 2009; Bjursell, 2015; Harvey, 2012; Ropes, 2013; Tempest, 2003). The goal of intergenerational learning in these environments is evolving from an emphasis on transfer of knowledge from the more experienced (i.e., older) person to the less experienced (i.e., younger) to promoting the co-creation of knowledge, values, and innovation (Bjursell, 2015). While the concept of generations is not homogeneous and fixed, it is commonly used to name cohorts in a population (e.g., baby boomers, generation X, millennials). Kuyken (2013) proposes thinking about generations as communities of knowledge that exist within age groups. Intergenerational learning then implies interaction between knowledge communities, where the reciprocal nature of the relationship is central.

Common forms of intergenerational relationships outside the workplace involve social interactions between such pairs as mentor/mentee, child/adult caregiver, and student/teacher that are dependent on each individual's contributions. These contributions to social interactions are influenced by a person's prior experiences and background knowledge, as well as their individual beliefs, values, and interests. These in turn are influenced by larger social structures including race, gender, culture, economics, and history. As participants engage in social practices they co-construct their positions (e.g., mentor, mentee) and views about their own and others' competence (e.g., expert, knowledgeable, novice) from their previous experiences in relation to the particular characteristics of the social practices in which they are engaged (Greeno, 2006;

Gresalfi, Martin, Hand, & Greeno, 2009, Varelas et al., 2011). In the case of the birder, when interacting with a teen who had no prior experience in bird banding, the teen was recognized by the adult and by herself as a novice, and positioned as the mentee. The adult who had many more years of experience than the teen, recognized herself in this situation as expert and positioned herself as the mentor. In a different case, an adult and teen were repurposing dead trees to create park benches. The teen designed and built a bench the prior year as part of a different informal science program. He brought with him some level of expertise to his new partnership. The adult had not built benches, but had experience in general woodworking. They each brought resources to the project and were positioned as competent during different phases of bench construction.

Youth/Adult Partnerships (Y/AP) is another model for intergenerational learning with an emphasis on the principles of youth voice in decision making and mutuality in teaching and learning (Camino, 2000). Y/APs involve youth in challenging, responsible actions that address recognized needs in a community, and give youth opportunities for planning and decision making that impacts others (The National Commission on Resources for Youth, 1976). Two principles of Y/APs that differentiate these partnerships from other adult-youth relationships (e.g., parent-child, mentor-mentee) are the emphasis on youth voice through opportunities for planning and/or decision making, and the goal of mutual learning. Each age group is seen and acts as a resource for the team (Camino, 2000). Three premises of Y/AP are: (1) strong communities are built on participation and civic engagement of all members including youth, (2) youth development requires a broad focus on building healthy communities - when youth participate and are not just beneficiaries they tend to experience optimal development, and (3) collaborating with youth to address community concerns can help adults overcome negative attitudes and misinformation about adolescents (Camino, 2000). While these partnerships have been effective in increasing youth participation and voice in community development (Camino, 2000), there is little research in other venues such as in community conservation work. How these partnerships affect learning and identity development of youth and adults is also absent from the literature.

Teens and adults do not habitually position themselves as equals learning new information together. Traditional forms of teaching and learning typically have the younger person learning from the older person (Cozzi, 1998; Bailey, 2009). This can be seen in the historical positioning of adult as teacher/expert and youth as learner/novice. Younger teammates are usually seen as knowledge-poor while older teammates are seen in comparison as knowledge-rich (Tempest, 2003). Senior teammates may have difficulty acknowledging that there is anything to learn from someone who is younger. They may feel their power threatened if they admit to ignorance about a topic, while younger teammates may feel uncertain and intimidated by the assurance and confidence of older partners. They may have difficulties communicating, and lack self-confidence to teach an older person (Bailey, 2009). The master-apprentice relationship is often thought of in this way, but under closer examination is found to be quite variable across space and time. Lave and Wenger (1991) found that more important than knowledge transfer from master (typically older) to apprentice (typically younger) is conferring legitimate peripheral access of the practices to the apprentice. The opportunities for learning are given structure by the work practices. “Learning itself is an improvised practice: A learning curriculum unfolds in opportunities for engagement in practice” (Lave & Wenger, 1991, p. 93).

Many people who do not develop a sense of themselves as able to understand, use, and contribute to a STEM field are missing opportunities for rewarding and well-paying careers and the literacy needed to guide them in personal decision making and problem solving. Most of all they miss out on the joy of discovery of the natural world. Informal science learning programs represent opportunities for people to develop and strengthen identification with STEM fields especially those people who never formed STEM identities in formal STEM learning environments. Intergenerational collaborative STEM learning is a novel strategy that may facilitate the development and strengthening of STEM identification in youth and adults. I now discuss the theoretical frame of STEM identity authoring used in this research and how it derived from psychological and social theories of identity.

# Chapter 2: Authoring a STEM Identity: The Complex Interplay of Structure, Agency, and Collaboration

## Identity Research Traditions

Different perspectives on the interaction between the individual and society provide a variety of theoretical frames for identity research. Before looking at the theoretical frame of STEM identity authoring that will be central to this current research, I first situate STEM identity within the broader context of identity research. I discuss differences between psychological and sociological identity theories, how the two can be integrated and how they relate to a STEM identity.

The term identity has a muddied history, with different understandings:

> It may, for example, mean no more than that a person or group is known by a certain name, but it may also be used in reference to the distinguishing characteristics marking whatever is known by that name or to the ensemble of cultural features that collectively constitutes the larger reality with which a person or group is identified through a certain name (Gleason, 1983 p. 930)

Identity has been researched from psychological and sociological perspectives. Two key divergences between these identity traditions are: (1) the extent identity is conceptualized as having inner vs outer origin, and (2) the prominence of structure or agency for understanding identity (Cote & Levine, 2002).

### *Differences Between Psychological and Social Theories of Identity*

The psychological tradition of identity theories stems from Erik Erikson's ego psychoanalytic theory in which he described three dimensions of identity: (1) ego - the subjective sense of continuity of self - of being the same person over time and in different situations, (2) personal - the behavioral and character repertoire that differentiates individuals - concrete aspects of individual experience rooted in social interactions, and (3) social - a person's position(s) in a social structure, their recognized roles in a community. Identity is seen as located in an inner core that is permanent although influenced by social interactions. The point of origin of agency is also considered within the person while transpersonal contexts work to constrain and enable the individual's agency (Cote & Levine, 2002).

The sociological tradition evolved out of Herbert Mead's work on symbolic interactionism which addresses how society is created through repeated interactions among individuals (Carter & Fuller, 2016). Identity in this perspective is located outside the individual and is continuously re-created through social interaction. From Mead's perspective, agency is concerned with a series of cognitions embedded in dialogical contexts. The person's agency is predominantly shaped by external forces manifested in interactions with others. From this perspective, active structural mechanisms within the person are missing; inside the person is treated like a black box. (Cote & Levine, 2002).

***Integration of Psychological and Social Theories***

As disciplines, psychology and sociology both recognize interpersonal contexts, providing a space where the two traditions can be integrated (Cote & Levine, 2002). As a concept, identity has the potential to act as a fulcrum between cognitive and social development (Lee, 2017). Who a person feels they are, their core or ego identity, is intimately connected to behaviors such as effort and persistence in goal attainment (Lee, 2017). According to Erikson, "the crux of identity stability in any culture lies in the interplay between the social and the psychic" (Cote & Levine, 2002 p. 16). Social institutions (e.g., family, school, religious community, etc.) are pre-conditions to the developing self and act as a matrix for the development of all behavior. A person's sense of ego identity is dependent on validation of their role and sense of integration in a community. Interacting with significant others and social institutions is the main source of ego strength (Cote & Levine, 2002).

Following Erikson's theory, a STEM identity is a kind of social identity. It follows that validation of one's social identity in regard to one's position and recognized role in a STEM endeavor can work to strengthen and stabilize a person's overall ego identity helping them to develop agency and persist in STEM fields. While identities are never static, some become more sustained than others. Developing a sustained STEM identity may work to strengthen a person's ego identity, but the development happens in the social world through engagement in practices with others and in constant tension with social structures.

Next, I discuss the theoretical lens of social practice theory and its relationship to STEM identity authoring used to frame this study. Important for my study, this includes: (1) how a STEM identity is conceptualized, (2) the three main constructs of a STEM identity, and (3) how social structures can affect the development of a STEM identity.

**Social Practice Theory and STEM Identity Authoring**

STEM identity authoring is grounded in social practice theory, a theoretical lens that focuses on interpersonal interactions during engagement in practice within local and socio-historical structures (Carlone, 2012). Activity is a central focus of social practice theory, but the development of persons in practice is also emphasized, with close attention to participant differences that may give rise to struggles due to these differences. Social practice theory emphasizes cultural production - the ways everyday practices produce cultural meanings that reflect or counter larger social structures. As people participate in their world, they are shaped by it as they in turn help to shape it (Holland & Lave, 2009). In this way, practice links global (macro-level structures) with local (micro-level structures) making it centrally located (Carlone, 2012). Three theoretical assumptions from social practice theory are: (1) identities are formed in practice (Carlone, 2012); (2) individuals have agency, but may be constrained by historical, social, institutional, and local structures (Holland, Lachiotte, Skinner, & Cain, 1998); and (3) social identification is a process that evolves over varying timescales (Carlone, 2012).

Take for example, a youth learning about environmental issues in school. The youth is concerned about pollution and its effect on his local river and joins a river clean up. As the youth participates in this group, he learns more about the problem and wants to become an environmental activist and contribute to public awareness of water pollution issues. Over time - through participation - the youth may help to change the practices within the group, and with multiple positive experiences the youth comes to identify as an environmental activist. Say, however, that the youth is African American, Latinx, or lives in a lower socio-economic urban neighborhood, and the environmental organization is composed of mostly white, middle-class suburban adults. Race, ethnicity, socio-economic, and family background may affect how the youth perceives himself in this context or is perceived by others in the environmental organization and affect how the youth is allowed to or chooses to participate.

Social practice theory responds to the educational problem of structure vs. agency by acknowledging that developing an identity includes both individual choices and societal constraints based on macro-level structures such as gender, class, and race. The structure-agency dialectic provides a tool for understanding complex social systems and to bridge levels of activity from micro to macro (Bronfenbrenner, 1976; Varelas, Settlage, & Mensah, 2015). It is however, often seen as over-emphasizing agency (Holland et al. 1998; Lewis & Moje, 2003) and under-examining structures (Shanahan, 2009). Recognizing the dialectic nature of structures and agency is especially important for historically marginalized populations who have often been positioned as deficient. This dialectical focus exposes external social forces that may inhibit access, participation, learning, and achievement. But it is also hopeful, recognizing the ways different actors (e.g. individuals, communities, institutions, and educators) demonstrate agency as they work to position themselves as STEM-capable. It is important to note there are also structures that enable agency and while agency is influenced by social structures, it also has power to shape those same structures (Varelas, Settlage, & Mensah, 2015).

Using identity as an analytic lens in STEM education is valuable because it points to important research questions such as: (1) What kinds of people are promoted or marginalized in science learning spaces?; (2) How do learners come to see the worth of engagement in science as a set of experiences, skills, knowledge, and beliefs?; (3) How do learners' emerging science identities involve changes to their more enduring identities and to possible future identities?; and (4) How can science education be more equitable for underrepresented students? (Carlone, 2012). Understanding the many factors that affect identification with a STEM field for diverse populations is crucial to developing effective STEM educational programs (both formal and informal) that promote lifelong STEM identities for all. I now examine different ways STEM identity has been conceptualized and the constructs that have been found to be important in authoring a STEM identity that will be central to this current research. The examples that follow were derived from data collected during year one of the project and are not part of the data set used in this research.

***Conceptualizing a STEM Identity***

Identity is a concept used in different social science fields with a confusing complex of connotations and research purposes (Cote & Levine, 2002). A variety of definitions of identity derive from the dual questions – "who do I think I am?" and "who do others think I am?" (Brickhouse & Potter, 2001; Gee, 2000; Moore, 2008; Nasir, 2011). STEM identity narrows the field to conceptualizing how a person views themselves in relation to the disciplinary fields of science, technology, engineering, and math (i.e. how a person feels that they can understand, participate, and contribute to a STEM field). Development of a STEM identity has been conceptualized with both intrinsic and extrinsic factors (Aschbacher, Li & Roth, 2010) reflecting cognitive and social constructs. Intrinsic factors such as interest (Hazari, Sonnert, Sadler & Shanahan, 2010), self-efficacy, and competence beliefs (Eccles, Fredricks, & Baay, 2015), as well as extrinsic features such as participation (Crowley, Barron, Knutson & Martin, 2015), recognition, sense of community and affiliation (Carlone & Johnson, 2007) are all thought to be involved, although there is disagreement whether certain constructs drive identity formation or are a part of identity (Vincent-Ruz & Schunn, 2018). The tension between intrinsic and extrinsic factors can be seen as an agency-structure dialectic within identity frameworks. These constructs mostly align with either cognitive science or social science, with intrinsic factors (part of identity) studied primarily by cognitive scientists and extrinsic factors (drives identity formation) studied primarily by social scientists.

Perez, Cromley and Kaplan (2014) conceptualize STEM identity as a part of personal and collective identities where individuals are unique due to highly valued characteristics that connect them to salient social groups. The emphasis is on intrinsic characteristics where agency through choices is the mechanism by which individuals enact and validate their identities. Following social practice theory, identities are continually formed in practice with others in an ongoing struggle between agency and structural constraints. Archer, et al. (2010) conceptualize STEM identity as both embodied and performed constructions realized through the tension between an individual's agency and the constraints in their specific, structural locations. The person's conception of their identity is as much who they are as who they are not. Carlone and Johnson (2007) emphasize the structural component of identity, echoing Gee's (2000) definition of identity as, "[b]eing recognized as a certain 'kind of person,' in a given context" (p. 99). Science identity is not merely what an individual says about her relationship with science or how she feels or acts, but it also entails needing to be recognized for her competence and performances and accepted in the field by meaningful others - meaningful to her (Carlone & Johnson, 2007).

***STEM Identity Constructs***

Following social practice theory, Carlone and Johnson (2007) developed an initial model of science identity, taken up in this current research, that includes three constructs found to be important to developing an identification with a science field: (1) competence - knowledge and understanding of core concepts useful in scientific pursuits of consequence; (2) performances - patterned sets of actions performed by members of a group based on common purposes and expectations, with shared ways of talking and using tools (Carlone, 2012; Kelly, 2007; Lave & Wenger, 1991); and (3) internal and external recognition of science competences and performances. Competence, performances and recognition combined as a science identity often are in tension with social structures that emphasize racial, ethnic and gender identities (Carlone & Johnson, 2007; Hazari, Cass & Beattie, 2015). Each of these STEM identity constructs is discussed next.

**Competence.** Science competence, “knowledge and understanding of science content” (Carlone & Johnson, 2007 p. 1191), refers to scientific skills or knowledge that are acquired through experiences, training or other external interventions and can develop over time into areas of expertise (Klieme, Hartig, & Rauch, 2008). As the teen participant, L, in the excerpt below participated with her adult partner in bird banding, she was learning important concepts in bird biology and ecology:

> And the fat is important. Why is the fat important L do you remember? (First year Adult participant).

> Because they need the fat stored up to migrate places in winter. So, if we can see how much fat they have we can see that they're pretty well off and that they've been eating a lot and wherever they've been stopping is a pretty good migratory stopover place (First year Teen participant).

L demonstrated competence when explaining the importance of the amount of fat for bird migrations. She now understands the importance of habitat for migratory birds to provide them with enough food to fuel their long-distance flights. Over time, the teen's participation in bird banding may lead to her being considered an expert in the birding community. Being competent in science knowledge is often viewed compared to a priori definitions of good science. An individual's meaning of competence is then measured against this definition (Carlone, 2012; Kelly, Chen, & Crawford, 1998). L may see herself as knowledgeable about birds and bird banding, but her definition of competence is measured by what the birding community considers as competent. Rather than considered an intrinsic trait of individuals, competence is constructed through individuals' opportunities to participate and demonstrate their competence with others (Carlone, 2012; Carlone, Haun-Frank, & Webb, 2011; Gresalfi et.al., 2009). Erikson (1968) postulated that humans are predisposed to attempt to gain mastery when interacting in social environments which constitutes a drive for competence. But, competence only becomes part of identity when it is recognized, "Identity resides at the intersection of competence and connection: this is where people feel most fully themselves - and are most recognized by others as being who they are" (Josselson, 1996 p. 178).

In summary, competence is defined by group-level meanings that determine what it means to be competent in a setting (Carlone, 2012; Gresalfi et al., 2009; Lottero-Perdue & Brickhouse, 2002) and involves the interaction between opportunities to participate in performances and how the individual and group recognize (interpret the meanings of that participation) - as demonstrating competence in scientific understandings or not (Carlone, 2012; Carlone et al., 2011; Gresalfi et al., 2009). Competence then, is tightly intertwined with performances. The quote from the adult and teen participants above demonstrates the knowledge and understanding of migratory bird ecology that L was learning as she participated in a bird banding project. The adult participant recognized her developing competence by prompting her to share what she had learned with the researchers.

Many students who do not demonstrate recommended levels of competence in school, including those from non-dominant groups may show competence on the same content in out-of-school learning environments (McLaughlin et al., 2001). For example, the Mesa program is an informal, co-curricular program that supports low socioeconomic, minoritized students in nine states based on an academic enrichment model initiated in California (Denson, 2015). One program component engages students in an annual engineering competition. Mesa participants outperform non-Mesa public high school students in math and physic course grades, completion of advanced physics and mathematics classes as well as college entrance exams (Denson, Stallworth, Hailey & Householder, 2015; Kotys-Schwartz, Besterfield-Sacre & Shuman, 2011).

Studying out-of-school learning can help teachers use what students have learned in informal spaces to build on students' understandings in formal spaces (Rosebery, Warren, Ballenger, & Ogonowski, 2005). Creating learning environments where students can learn disciplinary knowledge and practices and develop practice-linked identities is important for the purposes of educational equity and social justice (Bell, et al., 2017). ISL environments are potentially rich areas for developing competences while immersed in consequential pursuits with others, and provide opportunities for recognition of competence with potentially meaningful others.

**Performance of Scientific Practices**. Performances are the shared ways of talking and using tools by members of a group based on common purposes and expectations. They are the actions involved in creating and sharing new competences in scientific knowledge and understandings. (Carlone, 2012; Kelly, 2007; Lave & Wenger, 1991). In the bird bander example, performances included methods of capturing and retrieving birds from specialized nets, examining birds and recording important characteristics in a birder database, and communicating with each other using specialized vocabulary such as “fat pads,” “brood pouches,” and “migratory stopover.” These are all common practices within the birding community, and help birders learn about bird biology and ecology and make sense of why these birds are found in these specific locations. Performances of scientific practices support the development and refinement of explanations or solving problems and include investigative, communicative, and epistemic practices that are useful for working to understand something or in making stronger knowledge claims. Investigations involve inquiry practices such as observation, data collection, problem solving, and testing ideas. Communicative practices are necessary for collaborations and for dissemination of scientific information and include question-asking, generating interpretive inscriptions, and discussions. Epistemic practices are involved in sensemaking and include inferring, justifying, evaluating, and legitimizing scientific knowledge (Kelly & Licona, 2018). Performances are situated in their local production through the interactions of different participants and their historical traditions (Carlone, 2012). Bird banders have distinctive ways of investigating questions about birds, as well as using technology to collect and communicate that information to share with each other and the larger community of bird scientists.

**Recognition**. The following excerpt came from an adult engaged in an intergenerational partnership with a teen to build benches:

> Actually, in that situation, it was me asking him questions because he knew more about it than I did. I think allowing him to be in a position to teach me how to make the bench allows him to be more confident about his ability to make the bench. [adult first year participant]

This excerpt exemplifies how recognition unfolds in the context of pursuits, which is important since Gee (2000) notes how recognition is at the heart of identities. Positive recognition is based on demonstrated competence with scientific knowledge and understanding and successful performances of scientific practices (Carlone & Johnson, 2007). As individuals engage in the practices of science across time and space, they come to be recognized and positioned in relationship to science (Barton, Tan & Rivet, 2008; Carlone, 2004; Kang, et al., 2019; Polman & Miller, 2010). Positive recognition can be in the form of praise, special privileges, and gifts and acts as confirmatory feedback helping individuals to integrate and refine their target identities, while negative feedback works against the integration of identities (Kerpelman, Pittman & Lamke, 1997; Todd & Zvoch, 2017). For external recognition to support the development of a STEM identity, it must be internalized by the individual as self-recognition and then may manifest in social performances. Studying only the external performances of a person in order to understand development of identity has limitations in a possible mismatch between external performances and internal designations (Hazari et al., 2015). While the adult recognized the teen's competence in designing and building benches, it only becomes meaningful for the teen if the teen internalizes that recognition as an accurate assessment of his competence and it confirms a version of who he sees himself becoming.

People can make active bids for recognition through a combination of behaviors (e.g. ways of speaking, dressing, using tools, facial and body expressions, etc.) or leave themselves open to being recognized in a certain way. Recognition of scientific competences and performances by meaningful others has been found to be important to the development of a sustained STEM identity (Carlone & Johnson, 2007). Gee (2000) also emphasized that identity depends on recognition by oneself or others as “acting and interacting as a certain kind of person or even as several different kinds at once in a given time and place” (p. 99). Certain behaviors cue observers into an individual’s requests for recognition. How individuals make bids for recognition provides insight into the identity work of the person by showing what they think is important (Carlone, 2012). Bids for recognition show when individuals perceive their behaviors aligning with the privileged in the local culture (Carlone, 2012; Gee, 2000). Another behavior indicating recognition is “holding the floor.” The person who is able to hold the floor for extended time identifies who counts in a community by holding others’ attention (Carlone, 2012). Carlone & Johnson (2007) found that women with disrupted science identities had their bids for recognition ignored when they were recognized not for their science competence but as women or as representatives of their racial or ethnic group. Issues of conflict can also bring out struggles between celebrated identities and preferred or aspiring identities.

Carlone and Johnson (2007) found that while competence and performances were important, they could not predict the development of a successful science identity in the women they studied by these two constructs alone. The source of meaningful recognition from others was predictive of the type of science identity that emerged. Recognition from scientific others was important for a research identity. Recognition from others with similar altruistic aims or from the people they would be helping was important for an altruistic identity. Negative recognition from scientifically meaningful others due to gender, race or ethnicity contributed to a disrupted science identity. The type of recognition a person receives can promote or marginalize their identification with STEM subjects.

Recognition that depends on demonstrations of scientific competence and performances connects the constructs of STEM identity. But recognition of other identities may work to promote or constrain identification with STEM fields (Archer et al. 2010; Brown, Mangram, Sun, Cross & Raab, 2017; Carlone & Johnson, 2007; Ceglie, 2011). In any social setting, available roles and possible actions vary with institutional arrangements and requirements for access to these roles, along with persistent patterns of privilege, exclusion, and marginalization (Lave & McDermott, 2002; Penuel, Van Horne, DiGiacomo, & Kirshner, 2017). Internalizing recognition from others involves interpretation of interpersonal interactions that position one as STEM capable or not.

***Effect of Social Structures on STEM Identity***.

While not a construct of STEM identity, social structures are centrally important as they can support or constrain a learner's agency in regards to STEM disciplines, and may affect their developing STEM identity. Developing a STEM identity is a social process. To recognize oneself as a science person, one must also be recognized by meaningful others as a science person. To understand who a learner seeks to be, we must also understand who others are asking them to be in specific learning communities (Carlone & Johnson, 2007). "The space of authoring, of self-fashioning, remains a social and cultural space, no matter how intimately held it may become. And, it remains, more often than not, a contested space, a space of struggle" (Holland, et al., 1998 p. 282). Allen and Eisenhart's (2017) study of how four young women of color negotiated STEM-related identities in high school, found that the young women struggled against local narratives of race and class derived from larger more enduring historical conflicts. These narratives position students of color as underachieving, lacking motivation, doubting their academic ability, and missing social supports needed to successfully navigate high school. These struggles involved conflicts at the institutional or political level, as well as at the local day-to-day level. The women experienced tension around what it means to be, act and look like someone who is African American, female, scientific, and a good student, when performances of these identities do not align within particular contexts.

The recognition of a person's identity is underwritten by an interpretive system. People view nature with different historical and cultural perspectives; institutions have different norms, rules, and traditions; people have different modes of discourse; and affinity groups have different practices and underlying structures. The same identity may be construed in different ways and people can accept, negotiate, or contest how their traits are seen by themselves and others (Gee, 2000). Using the lens of STEM identity authoring derived from social practice theory, this study will explore how intergenerational collaborative partnerships support or constrain identification with science and technology for adults and teens by looking at the opportunities to demonstrate competence in knowledge and performances and the types of recognition incurred.

# Chapter 3: Methodology and Research Design

## Research Context

The overall goal was to investigate how intergenerational collaborative learning partnerships in an informal STEM program may affect STEM identity-authoring for teens and adults. This research was part of a larger multi-year NSF-funded collaborative project among the natural resources and education departments and the land use research center of a large public university on advancing informal STEM learning (AISL). The NSF- funded project designed the Intergenerational Conservation Partnership (ICP) program [pseudonym]. In the ICP program, high school students and adult community partners participated in two-day workshops to learn how to incorporate geospatial technologies and conservation science into community land use projects. The partners continued working on their collaborative projects up to a year past the two-day workshop and culminated in a presentation at a local conservation conference.

Five workshops over two years were held in five different locations across a northeastern state in the U. S. Two workshops were held the first year, the first on the campus of a large rural public university in the state's eastern region, and the second on the campus of an urban environmental charter high school in the state's southcentral region. Three workshops were held the second year. The first was held at an environmental education center in the southwestern part of the state, the second on the campus of an urban STEM magnet school in the central part of the state, and the third on the campus of a small private rural high school in the northwestern part of the state. All locations used classrooms for computer-based components of the modules and nearby streams and open spaces for field experiences. The workshops and further participation in the project were free for all participants. The intent of the workshops was to build intergenerational partnerships to enhance both adult and adolescent learning through mutual engagement in instructional modules and field experiences in preparation for implementation of an intensive community conservation project of their design. The intergenerational partners then worked together throughout the year with ongoing support from natural resource scientists at the university. The projects culminated in a poster presentation at one of two conservation/land trust conferences.

**Participants**

There were 32 level one participants (i.e., participants who attended the workshop and completed surveys) in year one of the project (15 adults and 17 teens) and 66 level one participants in year two (29 adults and 37 teens). Fifty percent of the participants were female, 79.2% identified as Caucasian, 11.2% identified as African American, 9.2% identified as Asian American, and 6.1% identified as Latinx. About 47% of the participants described their community as suburban, 17% as urban, and about 36% as rural. Over the two years, there were 42 teams of adults and teens each working on a collaborative community project.

Teams were recruited following the two-day workshop and informed consent was obtained from the participants and from a parent or guardian for the teens.The criteria used to select level two participant teams (i.e., participant teams agreeing to be observed in the field and interviewed) included the following demographic components associated with underrepresented populations in STEM: (1) sex (e.g., female), (2) ethnicity/race (e.g., African Americans, Latinx), and underrepresented communities in STEM geographical designation (e.g., urban, rural). Teams were also selected to encompass different types of previous and current relationships in the intergenerational teams (e.g., previous teacher/student pair, current teacher/student pair, and previously unacquainted pairs), as well as a variety of different types of adult experiences working with non-related youth (e.g., none, teacher, community youth worker, etc.). Originally five cases were selected each year for more in-depth study. In year one, one team declined to participate and a second team did not continue the project after the first field observation. A similar situation occurred the second year with one team ending their collaboration after the first field observation and a second team deciding to work on the project asynchronously. For this research, three cases were chosen from year two of the project. Following is a more detailed description of each team using information from the pre-survey. Each team is numbered for convenience and does not signify any type of hierarchy. Pseudonyms are used throughout.

### *Case One*

Walter was a 16-year-old African American male from an urban township who attended an early college magnet high school. As a hobby, he collected and reared native and exotic arthropods and also enjoyed studying them in their natural habitat. He also enjoyed teaching his friends and family about science and the natural world. He felt he knew a lot about entomology and was planning on majoring in entomology or ecology in college. Ernest, his adult partner, was a 62-year-old Caucasian male who had also been Walter's middle school science teacher. He had a bachelor's degree in natural resources and conservation and felt he knew a lot about his state's natural history. As hobbies, he enjoyed native plant landscaping, creating insect collections, and pressed botanical collections.

### *Case Two*

This case began as a group of four with three teens and one adult. All of the teens were enrolled in a program to support future first-generation college students. Two of the teens, however, dropped out of the project before completion. Anna, a 17-year-old Latinx female left the project soon after the workshop when her family returned to Puerto Rico, and Stephen, a 17-year-old African American male participated in the project in its early phases, but stopped participating after data collection ended. Julie, a 17-year-old Caucasian female from an urban area, was the only teen to complete the project with their adult partner. Julie was in her senior year at a magnet high school where she was taking all college level courses and will be the first one in her family to attend college. She felt she knew a lot about environmental science and was considering majoring in natural resource management and conservation. Her adult partner, Miguel, was a 26-year-old Latinx male who lived in a suburb outside the city where Julie lived. He was pursuing a master's degree in a public health field while working at a non-profit which supports students who will be first generation college students like Julie.

***Case Three***

Case Three consisted of two teens and one adult. The two teens knew each other before the program, but had not met the adult previously. Keith, a 15-year-old South Asian American male from a suburban community, enjoyed gaming, drone flying, and robotics and felt he knew a lot about engineering. He didn't yet know what major he would like to pursue. Andy, also a 15-year-old South Asian male, was from a different though geographically close suburban area.. He was considering pursuing a college major in biology or computer science. Their adult partner, Ingrid, was a 55-year-old Caucasian female with a master's degree in mechanical engineering. She lived in a neighboring suburban community and enjoyed nature, cared about the environment and wanted to help encourage others to do likewise.

**Study Design**

This multiple case study (Stake, 2006) followed three cases (intergenerational partnerships) as they designed and implemented their conservation projects over the course of a year. Stake (2006) describes the target condition or phenomenon to be studied in a multiple case study as the quintain. Cases are examples of the quintain. In this study, the quintain was STEM identity authoring in intergenerational learning partnerships with each team representing a case study. Each individual participant was a subsection of the case. Purposeful sampling was used (Creswell, 2013) to facilitate exploration of differing perspectives among teens and adults from underrepresented groups in STEM, as well as different types of relationships in the intergenerational teams (e.g., teacher/student or previously unacquainted pairs). The study used a social constructivist framework (Creswell, 2013) in seeking to understand the participants' varied and multiple meanings of their program experiences. Social constructivism is an interpretive framework with associated philosophical beliefs that encompass the nature of reality (ontological), how people know about reality (epistemological), the role of values (axiological), and approaches to inquiry (methodological) that align with social theories of learning. Reality is viewed not as a single entity that exists apart from people, but exists in multiple forms created by individuals' experiences and social interactions. The researcher is included in the co-creation of reality with the research participants and reality is shaped by their individual experiences. Values are respected and negotiated among individuals. The researcher used open-ended questioning to allow participants to construct their own meaning of their experiences and recognizes that their background and experiences shape their interpretations (Cresswell, 2013). As such, it is important to understand my subjectivities that may relate to this research.

### ***Subjectivity Statement***

As a qualitative researcher, I realize that my personal beliefs and experiences will affect all phases of the study. I was a public-school teacher for over 20 years, teaching students from preschool through high school, but mostly teaching science to middle school students. I taught in four states in the midwest, southeast and northeast regions of the U.S., in urban, suburban and rural districts. I have worked and volunteered in informal spaces as diverse as swim and ski instructor, after-school program teacher, and various after-school STEM clubs. From my diverse experiences working with youth, I have developed personal views about effective ways adults can support youth in learning science. I am a strong advocate for the importance of relationship building between adults and youth through dialogue. I also believe that teaching and mentoring is not an innate trait of a person, but is a complex web of skills that can be learned. My approach to research is similar to science teaching in following a constructivist approach that focuses on each individual's opportunities for making meaning of their experiences.

I was also intricately involved in the collaborative refinement of the informal science learning program that is the context for this research project. I was employed as a graduate research assistant on this project to develop the research instruments and collect data. I attended meetings of the collaborative project team giving input on workshop components related to education. During the workshops, I presented information to the participants about the research component investigating intergenerational collaborative learning.

***Data Collection Procedures***

Data collection procedures included field observations of teams working together on their conservation project. Field observations consisted of 30 - 60 minute sessions of the teen(s) and adult collaborating on a particular phase of their project. This included brainstorming project ideas, collecting data in the field, and designing posters or other types of presentations (e.g., videos, pamphlets, children's booklets, etc.). Observations were video-recorded so multiple viewings during the coding phase were possible and the observations could be shared with other investigators on the project. An observation protocol was adapted from Carlone (2012) to guide field notes and subsequent coding of video recordings. The protocol included sections on identity constructs for science and technology, as well as social interactions that represent larger social structures or group norms (Appendix A).

Teens and adult partners were interviewed separately immediately following each observation. Interviews were audio recorded with the participants' permission and later transcribed. During the first year, one standard interview protocol was used after each field observation. The open-ended questions related to the preceding field observation and possible demonstrations of the identity constructs and social structures. Over the course of the first year, I realized that using only one interview protocol was limiting. I was not asking questions about who or what might have initially motivated participants to want to participate in an informal STEM program such as ours. My initial interview protocol was modified to follow Seidman's (2013) model of in-depth phenomenological interviewing using a three-interview series protocol. The three-interview series protocol was modified to span the year-long community project and consisted of three interviews each lasting from 40 - 60 minutes. The initial interview was held before or early in the team's fieldwork and asked participants about their focused life histories. The objective was to reveal the participants' historical STEM identity (Appendix B). The original protocol remained as the second interview asking questions about the details of participants' experiences in the field working on their project. The second interview explored how working collaboratively on a community-based conservation project affected the participants' STEM identity. This interview asked questions about different science and technology identity constructs (e.g., competence, performance, and recognition) within the context of their project's work (Appendix C). The final interview reflected on the participants' meaning-making of their experiences throughout the year and looked towards a possible emerging STEM identity where they would seek out other opportunities to participate in STEM endeavors (Appendix D). Data collection also included artifacts such as final project posters, booklets, pamphlets, forum postings, and email communications.

***Data Analysis Procedures***

The analytical strategy that was followed in this study began with the theoretical propositions that underlie the design of this multiple case study (Yin, 2018). These included: (1) the theoretical lens of STEM identity authoring (e.g., constructs of competence, performance and recognition; Carlone & Johnson, 2007) that is reflected in the research question and shaped the data collection plan, (2) social structures that may constrain or promote STEM identification, (3) the design of informal science learning environments, and (4) intergenerational learning. The following more specific sub-research questions which derive from the original research question (i.e., How do intergenerational collaborative learning partnerships affect STEM identity authoring in teens and adults?) guided the selection of episodes and coding of units of meaning. Units of meaning were roughly anything that by itself could help to answer the research sub-questions.

a. What competences (i.e., knowledge and understanding of science and technology content) are activated and refined by learners as a result of participation in intergenerational conservation projects?

b. What performances (i.e., social performances of relevant science and technology practices—e.g., ways of talking and using tools) are enacted by intergenerational learners in conservation projects?

c. What kinds of recognition (i.e., recognizing oneself and getting recognized by others as a science or technology person) are demonstrated among intergenerational learners in conservation projects?

d. What social structures (e.g., group level norms, positioning) are evident that could impact participation in intergenerational conservation projects?

e. How is youth voice promoted or constrained in decision making in the intergenerational partnership?

f. How is mutuality in learning and teaching between the adult and teen demonstrated in the intergenerational partnership?

Data were analyzed through an iterative process consisting of four stages. An initial orienting pass through the data involved reviewing observation videos chronologically for relevant episodes and coding them first along with writing analytic memos. *In vivo* coding was used to better attune to the participants' perspectives and actions (Saldana, 2016). This was followed by coding related adult and teen transcribed interviews with accompanying analytic memos. Other artifacts such as research posters, email interactions or forum posts were used as secondary data sources.

Subsequent reviews of the data followed Groenewald's (2004) phase strategy for explicitation of the data. Groenewald uses the term explicitation to capture the intent of retaining the context of the whole while examining the constituent parts. This strategy recognizes the tension between the case and quintain in a multiple case study in attempting to attend to both the individual cases and the overarching phenomenon as well as the tension between units of meaning and developing themes. During the second stage of analysis, data were examined to identify "units of meaning" related to the constructs of STEM identity authoring (e.g., competence, performance and recognition; Carlone, 2012) that could be used to create individual learner profiles. Coding for structural factors that might affect these identity constructs also occurred during the second stage as these were used to develop case profiles. Identifying episodes that contained units of meaning enabled revisiting of units of meaning in the context in which they occurred. Episodes may contain one or more units of meaning and some units of meaning may include more than one construct reflecting the intertwined nature of STEM identity constructs. For example, a competence may be demonstrated through a performance and recognized by the participant and/or their partner at the same time. The following is an example of an episode that could be coded for a unit of meaning regarding competence:

> Basically, from beginning to end we're saying, first of all, we need to take out dangerous, dead trees. Second of all, that the tree is giving us those benefits many times over, so it's worth it to take them out. There's still that extra monetary value to replant a new tree. Then the last point was that once we've done that, why should we just chip up the wood

> and put it in the landfill where all that carbon eventually goes back into the atmosphere when we can use that wood to create furniture, like a bench or a chair, that will keep that carbon sequestered longer and have this extra benefit of just being an awesome piece of furniture. It's just all these benefits in a chain that help. (Noah, first year teen participant)

In this episode, Noah demonstrated competence in scientific understanding of the importance of trees in an urban ecosystem for multiple reasons including carbon sequestration that he learned while participating in this project. Units of meaning for competence in this episode include: (1) safety reasons for removing dead tress, (2) monetary value of replacing dead trees, (3) carbon release from dead trees added to land fills, and (4) carbon sequestration in trees used to make benches. Noah continued with a description of several performances with which he and his partner were engaged:

> The next step, what we're focusing on this year, is building several benches, putting them in parks around the greater [city] area that will link to a site that tells people what the project is about, how people can help with the project, and who's helping with it. We're gonna use a website like ArcGIS to make a map of where the benches are and possibly where the trees came from and stuff like that. It'll be a very, very long term...very complex project. (Noah, first year teen participant)

Noah and his partner were not only engaged in building benches out of dead trees from the urban parks of their community, they were planning to create an interactive website that will map the locations of the benches and provide educational information that the community can access. This episode included units of meaning that reflect technology performances (e.g. developing a website, using ArcGIS to create maps), as well as communicative performances (e.g. explanation of the project, and how people can help). Later in the interview, Noah described what it was like working with his adult partner, Hugo:

> He just really makes sure he's listening to my ideas and what I have to say. We just are able to bounce ideas off each other without immediately saying like, "No." We just listen to what the other person has to say and build onto that, give it constructive criticism, and use that to move on. (Noah, first year teen participant)

This excerpt includes units of meaning for social structures from the group norms that this intergenerational partnership established and which were foundational for how Hugo and Noah interacted. The units of meaning include: (1) listening to each other, (2) building onto what the other person has offered, and (3) constructive criticism.

The third stage of analysis involved reviewing the units of meaning to elicit their essence (Groenewald, 2004) in view of the research sub-questions to develop themes that represent clusters of salient units of meanings to answer the research questions. The units of meaning were grouped into themes that could be combined into profiles of each individual in the intergenerational partnership (i.e., cases). Themes may relate to: (1) the constructs of STEM identity authoring in teens and adults (e.g., demonstration of competence, performances of practices, types of recognition), (2) social structures in the intergenerational partnerships (e.g., how teams brainstorm ideas, methods of making decisions in the project, how student voice is encouraged, or how roles are assigned for particular tasks), or an emergent construct found important to the intergenerational collaborative partnership. The profiles for each participant were combined to form a case for STEM identity authoring in intergenerational learning partnerships.

The last stage entailed cross-case comparisons following Stake's (2006) track one strategy which emphasizes the situational nature and findings of each case study and helps construct knowledge about the quintain. This supports the objective of this research to better understand STEM identity authoring in intergenerational collaborative learning partnerships, both differences and commonalities across manifestations. Each case offers a situated understanding of intergenerational STEM identity authoring and the rationale of comparing cases is to further the understanding of the complexity of this quintain. This last stage will review the findings for each case and apply those findings to the research questions. This involves: (1) determining the expected utility of each case for further development of the themes, (2) rating the importance of each finding for understanding the quintain with regards to a particular theme (e.g., high importance, medium importance or low importance), and (3) determining atypicality or uniqueness of each case and how it might extend or constrain a multi-case assertion. For example, the team of bird banders might be expected to be instrumental in developing a theme related to the importance of performance of scientific practices due to the prominence of practices involved in bird banding episodes. Some findings from this case may be rated high or medium in importance for understanding intergenerational STEM identity authoring in relation to performance-based themes. The bench building team, on the other hand, might be expected to be instrumental in developing a theme related to competence from episodes where competence in knowledge and understandings features prominently. Some of the findings from this team may be considered of high or medium importance for understanding intergenerational STEM identity authoring in relation to competence-based themes. The most important findings rated high - or high and medium - for each theme from the different cases were reviewed to see if they can be synthesized into tentative assertions. These tentative assertions were then reviewed along with the evidence from findings and themes to develop final assertions.

***Reflexivity***

Researchers who use qualitative methods like those in this study use a variety of strategies to demonstrate reflexivity. Reflexivity is a continuous process of internal dialogue and critical self-evaluation about the researcher’s positionality (e.g., gender, age, race, values, beliefs, biases, behavior towards participants) and acknowledgement of its potential to affect all aspects of the research process and outcome (Berger, 2015; Bradbury-Jones, 2007; Guillemin and Gillam, 2004; Pillow, 2003; Stronach et al., 2016). In my research, I demonstrated reflexivity through a variety of methods: (1) writing analytic memos, (2) triangulating data, (3) peer review and debriefing, and (4) informal external audits by project programmers, external evaluators, and my dissertation committee.

Throughout the data collection phase, I reflected on what I thought I was learning by writing field notes and analytic memos. Writing analytic memos continued into the data analysis stage while reviewing, transcribing, and coding video and audio recordings. Taking detailed field notes and video recording and transcribing enhances the reliability of findings (Cresswell, 2013). The iterative process of data analysis also contributed to a continuous reflection of how information from new cases compared and contrasted to findings from previously analyzed cases.

To develop trustworthiness in research, Cresswell (2013) discusses triangulation of data as a validation strategy to document the accuracy of studies. Using multiple sources of data provides corroborating evidence to shed light on each theme. For example, when developing the theme of adult competence, evidence from pre-survey questions, observations of the partners in the field, interview responses, and project artifacts (e.g., pamphlets, presentation posters) were all examined and compared. Developing convergent evidence through multiple sources of evidence strengthens construct validity of case studies (Yin, 2018). The use of multiple interviews with similar questions helped to more accurately portray participant perspectives. Stake (2006) discusses triangulation across cases as reflecting on whether new views are consistent with what is already well known about the case and quintain. Triangulation across cases also involves checking with people who know something about the quintain or related activity. Continuing discussions with project team members during fieldwork and analysis facilitated this reflection.

Peer review or debriefing is an external check on the research process. Meetings with peer reviewers allow for the incorporation of other perspectives on methods, meanings, and interpretations (Cresswell, 2013). Throughout the research process, I met regularly with a co-principle investigator on the project to review all facets of research including selection of episodes, coding, and writing analytic memos. In year one, we coded data from two cases and developed intercoder agreement for STEM identity constructs also used in this research. Cresswell (2013) argues a key issue in developing interrater reliability is determining what the coders agree on. In this case we agreed on coding the same passages in the same way.

Finally, external audits support reflexivity by examining the process and product of research by individuals not directly involved in data collection and analysis. Their role is to look at whether or not findings, interpretations, and conclusions are supported by the data (Cresswell, 2013). For this research, numerous individuals acted as formal and informal auditors. All stages of the research were reviewed by the ISL program advisory board and external evaluators. Data and findings were reviewed by the ISL program team and by my dissertation committee.

Next, I discuss findings from analysis of the data on the three cases. First, I present a description of the three cases, followed by a cross-case analysis.

# Chapter 4: Factors From Participant Historical Identity, Engagement in Practices, and Social Structures That May Impact STEM Identity Authoring in Intergenerational Collaborative Partnerships

The three intergenerational cases examined here had many differences. The participants came from a variety of backgrounds. They entered the Intergenerational Conservation Partnership (ICP) program with different levels of competence in conservation science, technology, and other science fields. They had different informal experiences in STEM and different experiences related to nature and the outdoors while growing up. The adults ranged in age from 26 to 65 with varied experiences working with teens. In case one, the teen and adult were already well acquainted, while in the other two partnerships they had just met. To understand how experiences in the intergenerational project may have affected the participants as STEM learners and their identification with STEM disciplines, it is important to understand the STEM identity of each when they entered the program. Demographic information about the participants in each case was provided in the methodology sections. I now present a more extensive profile about each case and then discuss my findings from a cross-case analysis.

## Case Profile 1: Walter and Ernest – A Teacher and his Protegee

Walter and Ernest decided to participate in the ICP program together. Walter, a 16-year-old African American male from an exurban community, was in his junior year at an early college magnet high school. He came into the program with an already strong interest in conservation science, especially around insects. He credited his parents and science teachers - formal and informal - with most influencing his interest in science. Walter was earning mostly As and Bs in school while taking upper level high school and college level classes. He wanted to take part in this program to, “learn ways I could help to conserve wildlife in Connecticut, especially insects. I also want to learn how to teach others about the importance of biodiversity in ecosystems." Walter was also intrigued to learn technology that could help him further his studies about insects:

> I was interested in learning more about the technology aspect and working on another project that involved environmental issues because I'm really interested in that kind of stuff. The technology aspect sounded interesting too, especially with Trackit, and so I can map out different areas of trails and things like that, where I find interesting things to come back to. I was excited to work on that for this project.

Ernest, a 62-year-old Caucasian male, had a bachelor's degree in natural resources and conservation and had been Walter's middle school science teacher. Ernest wanted to participate in the ICP program because "I have very high hopes for Walter in his pursuit of an environmental education and also to better learn how to do GIS and mapping." Ernest viewed the program as one cog in Walter's trajectory to become an entomologist. Ernest explained how they wanted to participate to learn the mapping techniques to use on Walter's tiger beetle project. He also wanted to learn the technology for himself, "I was hopin' to finally learn how to do somethin' with technology, but I have a flip phone, and I can't really afford buyin' all this expensive stuff and everything else, so I was hopin' to learn about it myself." He also planned to teach the technology to other teachers, "You have three times a year that the staff teachers put on a project and then other teachers sign up to go with them. I signed up to do this, the Track Kit."

Walter and Ernest decided to do an awareness project of the biodiversity of an urban park near where Walter lived. The partners presented a unique case in that they were already well acquainted with each other before the ICP workshop and had chosen to attend and engage in a collaborative project together. This presented a different type of working. In earlier experiences, Ernest was not a participant in the learning program, but acted as Walter's teacher or coach, and the focus was on Walter's learning. In the project, the pair worked as partners making decisions together throughout the project.

**Case Profile 2: Julie and Miguel – Strangers to Community Partners**

Miguel and Julie learned about the ICP program through the college access nonprofit where Miguel worked, and Julie was a client. Miguel was asked to recruit students for the project but was interested in becoming a community partner himself. Originally, there were three students in the team. The students and Miguel did not know each other before participating. One student dropped out when her family moved back to Puerto Rico. The second student, Stephen, left in February after he stopped contributing to the project.

Julie, a 17-year-old Caucasian female, lived in an urban coastal community in southern New England. She attended a dual enrollment magnet high school on the campus of a community college which enrolled students in 11$^{th}$ and 12$^{th}$ grades who were allowed to take courses for college credit. Julie had just completed her junior year earning mostly As and Bs and was looking forward to taking all college level courses her senior year. She would be the first in her family to attend college. She credited her father, and a high school science teacher as being most influential in her interest in science. Julie did not consider herself a science kind of person although she identified with environmental science. She indicated interest in a broad range of topics and activities related to the environment: (e.g. birding, climate change, environmental activism, forestry, gardening, habitat restoration, local government, nature photography, river and park cleanups, and water quality). She felt she knew a lot about environmental science and was considering majoring in natural resource management and conservation. Julie decided to take part in the ICP program to learn skills she would need in her future career working in natural resource management.

Miguel, a 26-year-old Latinx male, was pursuing a master's degree in public health while working at a non-profit providing support to first generation college students. Originally from a southwestern state, he was living in a neighboring suburb of the city where he worked and where his ICP partner, Julie, lived. Miguel gave credit to a host of people who influenced his interest in science from family members to public figures like Neil DeGrasse Tyson. He chose to become involved in this program because he felt it was a "great way to engage local high schoolers and the community with problems they may not realize are happening in their neighborhood." Miguel considered himself a STEM kind of person having majored in number of science fields including physics and biology before settling on anthropology. Miguel couldn't recall ever having a negative experience in science but explained that it was probably the result of his outlook that everything is a learning experience.

Julie and Miguel decided to participate in ICP because each saw an alignment of their personal and career goals with the goals of the program. Julie was planning on majoring in natural resource management, "Because it's [part of a larger natural resource organization], and I want to do natural resource conservation as the major in college." She volunteered to take part in thre ICP program after Miguel asked if any students at the nonprofit were interested in a project involving biology or natural resources. Julie saw from the flyer that it was about conservation and natural resources, "he just asked if anyone is interested in biology or natural resource environment and such, so, I was like, 'Yeah, it's me,' so he showed me the flyer, I was like, 'Yeah, I'll do that.'"

Miguel's interest in a public health career came from a desire to help lower income people live healthier lives. He viewed the environment from a public health perspective recognizing the potential impact on health of knowing about your local area and outdoor environment:

> My own personal and academic interests lie a lot with community health and that's why I'm doing this. One of the big things that helps improve the general health of the community is more of an educated populace. This just goes hand-in-hand with my own academic interests. One of the other things that I'm a big advocate for is, number one, being educated about the area that you live in and the environment.

Miguel was concerned about how disconnected people have become from nature and how that affects their physical and mental health. Rather than giving a pill to someone who has become depressed, Miguel mentioned prescribing more time in nature:

> but number two, seeing that oftentimes in healthcare - and again, this is coming from an academic interest - the answer's usually here's a pill. I haven't really heard of any doctor saying it like, "You seem like you've been down recently. When's the last time you took a walk outside?" It's like, yeah, surprising how much nicer you feel after going on one of those, going on a walk.

Miguel was also interested in getting involved with the community and mentoring students, "For the longest time, I was looking for ways to get involved within communities, and especially with students and working on outdoors, natural resource access, things like that." The ICP program presented an opportunity for Miguel to apply his breadth of knowledge and experiences in STEM fields through his lens from anthropology and public health to a community conservation project, while also developing his skills as a mentor.

Julie, Miguel and Stephen decided to do an urban green spaces awareness project in the town where Julie and Stephen lived. Julie and Miguel brought very different backgrounds and resources to the project. Julie lived her whole life in the target community. Miguel grew up in the southwestern U.S. and had traveled extensively. Both were committed to the community where Julie lived, and Miguel worked.

**Case Profile 3: Keith, Andy and Ingrid – Newcomers to Conservation Science**

The third case study consisted of three participants, two teens – Keith and Andy, and their adult partner, Ingrid. Ingrid did not know either teen before meeting them at the CTP workshop. The teens were friends who had lived in the same town, although they now lived in different towns and attended different high schools.

Keith, a 15-year-old South Asian American male from a suburban community, enjoyed gaming, drone flying, and robotics. He felt he knew a lot about engineering but didn't yet know what major he wanted to pursue. Keith was a sophomore in high school earning mostly As. He had already taken a number of science classes and AP computer science. He credited his parents, science teachers and out of school science leaders for his interest in science. Keith found out about the ICP program from his science teacher and he thought, "it would be a fun, interesting program through which I could learn about local environmental problems."

Andy was also a 15-year-old South Asian male from a geographically close suburban area. Like Keith, he credited his parents and science teachers - both formal and informal - for influencing his interest in science. He earned mostly As in school, enjoyed reading science texts and felt he knew a lot about biology. He was considering pursuing a college major in biology or computer science. He wanted to attend the program, "to understand about my surrounding nature and create a safe environment for all living things due to my interest in biology." Andy learned about the program from his parents:

> My friend Keith, his parents told my parents about this program. I thought it was an interesting program to get to know other students. Since Keith was going there, my parents thought it was a good idea for me to go there, too, and learn new things about [the] environment.

The possibility of connecting with other students seemed to be important to both Andy and his parents. They may have confused the ICP program with a similar conservation program (SCP) where teens spend a week on the same university's campus with other students.

Ingrid, their adult partner, was a 55-year-old Caucasian female from a neighboring suburban town. She had a master's degree in mechanical engineering and credited her siblings for influencing her interest in science. Ingrid enjoyed hiking and other outdoor activities and cared about conservation issues. She wanted to help encourage others to do likewise. Ingrid was interested in participating in the ICP program from the positive experience her daughter had participating in the SCP program:

> She [her daughter] participated in that [SCP] program, and I just thought it was an awesome concept. I thought that the experience she had up at [university] was fantastic. She had got a lot of really good experience with learning about conservation efforts and methods and technology.

Ingrid believed real-world practical experience is important for youth and was interested in becoming involved in such a program:

> This is the kind of learning you need to do, where you actually apply the things that you learn in the classroom. Also, just from the perspective of community involvement, I'm pretty passionate about that, too. Seeing this create this opportunity for kids to get involved in their own community and make those connections with leaders in the community and the local government or anything like that, is just awesome.

Ingrid, Keith, and Andy decided to do a research project on the presence of microplastics in a local river.

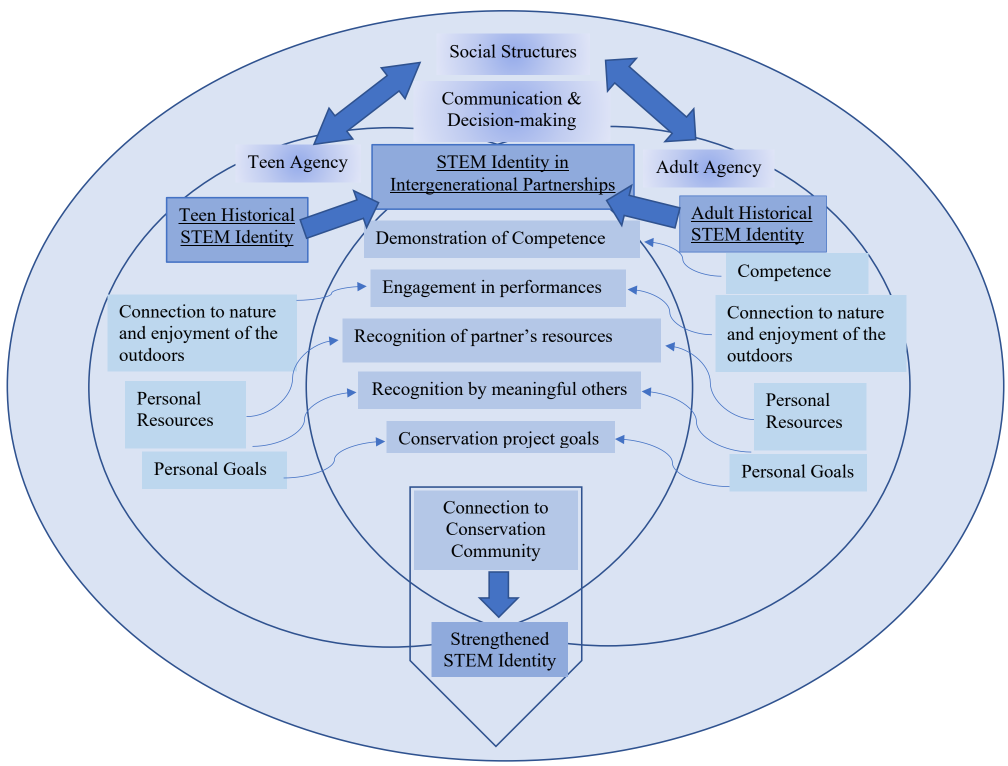
In the end, the teens and adults in cases one and two viewed their collaboration and final project as successful and felt they had contributed to conservation science. They felt recognized for their contribution by the larger conservation community and were proud of their accomplishment. Each participant in these two partnerships expressed a desire to continue working in conservation science in some capacity. In these two cases, participation in the ICP program may have strengthened their identification with conservation science.

In case three, there were discrepancies between how the adult and teens viewed their collaboration and the success. While stating they felt the project was successful, they did not feel they had contributed much to conservation science and did not feel recognized by the larger conservation community. None of the partners expressed a strong desire to continue in this work. In the third case, participation in the ICP program may not have strengthened their identification with conservation science. I now discuss the findings from my cross case analysis.

**STEM Identity Authoring Across Three Intergenerational Collaborative Partnerships**

Across the three cases, findings fell into one of three themes that worked to promote or hinder the further development of participant identification with conservation science and technology: (1) factors in the participants' historical STEM identity, (2) STEM identity constructs exhibited through engagement in the intergenerational project, and (3) overarching social structures in tension with participant agency. Figure 1 depicts how these three themes characterize the authoring of STEM identity in the context of an intergenerational team. The historical STEM identities of the teens and adults in the collaborative partnerships are represented in the two outer parts of the intersecting circles, respectively. Aspects of their historical STEM identities found to be relevant in this study (i.e., adult competence in conservation science, adult competence in mentoring, connection to nature and enjoyment of the outdoors, personal goals and other personal resources) are shown. Adults and teens bring their STEM identities and other personal resources that have developed over their lifespan to the intergenerational collaborative project (represented by the arrows pointing in).The inner intersecting part of the two circles represents the participants' experiences in the intergenerational collaborative project. The large outer circle represent social structures in which all social interaction is embedded. Possible tension between overarching social structures and participant agency in communication and decision making is shown by the double headed arrow between the teen and adult agency and social structures. The bottom large arrow depicts the combined outcome of all these factors in the opportunity to build connections to the conservation community and strengthen participant identification in conservation science and technology.

Figure 1: Interplay of intergenerational historical STEM identity and social structures on STEM identity development in intergenerational collaborative conservation projects




First, I discuss the factors in the participants' historical STEM identities that were found to be important for successful intergenerational collaboration and promotion of identification in conservation science and technology. Then, I discuss the factors in their experiences and interactions in the intergenerational partnerships found to be important for successful collaborations and promotion of STEM identities. Successful collaborative partnerships as recognized by the partners included: (1) demonstrating competences in conservation science, (2) engaging in performances of practice to complete their long-term project, (3) recognizing, valuing, and incorporating each partner(s) personal resources, (4) aligning project goals with personal learning goals, and (5) receiving recognition from meaningful others. Finally, I discuss the impact of social structures on the agency of participants. Performances such as communication and decision making between the partners may have been impacted by the tension between social structures (e.g., age, culture), and individual agency. Successful collaborations were found to promote teen agency in communication and decision making.

***Historical STEM Identity Characteristics***

The adults in the three cases presented here had many similarities. They each entered the program with a well-established STEM identity based on previous attainment of high levels of competence in science and engagement in scientific performances. All three expressed interest in mentoring teens and learning more about how to use technology to promote conservation. They all enjoyed and engaged in outdoor activities related to the environment. The four teens in these three cases also entered the program with strong identification with a STEM field. They had a range of childhood experiences in STEM, though not all pertaining to nature or the outdoors. They all expressed interest in engaging in a project that would help to address environmental issues. Across the three cases, three aspects of adult and teen historical STEM identities appeared to facilitate partnerships where participants furthered their identification with conservation science (i.e. they felt they were knowledgeable about, participated in, and contributed to conservation science). These are: (1) adult self-recognition of sufficient competence in conservation science to guide or mentor their teenage partner, (2) adult understanding of connections of global environmental issues to local communities, and (3) prior positive outdoor experiences in nature. (Table 1)

In contrast, participant self-recognition of historical competence, performances, and positive experiences in technology were not found to affect successful intergenerational collaborative partnerships.

**Finding 1: Adult Self-recognition of Competence in Conservation Science Promoted Self-recognition of Mentoring Competence in Intergenerational Conservation Collaborations**. The three adults in the case studies all entered the ICP program with well-established STEM identities and high levels of competence in science though in different fields. Ernest and Miguel recognized themselves as competent in conservation science while Ingrid did not. Ingrid recognized herself as competent in engineering and physics. Throughout the project, Ernest and Miguel enjoyed and felt competent in mentoring their students in a conservation science project and considered their projects collaborative and successful. Ingrid, however, mentioned several times she felt her lack of knowledge in conservation science created difficulties for her to be able to mentor her two teens, and did not feel they had achieved a high level of collaboration in the project.

Ernest recognized himself as competent in conservation science from a lifetime of teaching and learning about environmental issues. Ernest had a bachelor's degree in natural resources and conservation and felt he knew a lot about his state's natural history. He also felt competent to mentor students in environmental science with a history of mentoring students in various programs. Ernest was involved in science bowl at the middle and high school level and also MATHCOUNTS, a national program that provides middle schoolers with opportunities to compete with peers.. One of the ways Ernest tried to involve his students in conservation science performances was by initiating a BioBlitz - an intense period of biological surveying in an

*Table 1: Historical STEM Identity Charactreristics Important in Intergenerational Partnerships*

| Findings | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| (1) *Adult self-recognition of competence in conservation science promoted self-recognition of mentoring competence in intergenerational conservation collaborations* | Ernest entered the program with an already established identity as a mentor and as an environmental educator. | Miguel entered the program as a novice mentor but confident that his knowledge of conservation science was sufficient to guide three teens in their project. Miguel was knowledgeable about many fields of science having majored in physics and biology, finally settling on anthropology. | Ingrid had bachelor's and master's degrees in mechanical engineering. She developed Science and engineering competence through her love of cars and hands-on learning. She recognized her competence in physical science, engineering and technology but not conservation science. |
| (2) Adult understanding of connections of global environmental issues to local communities facilitated collaboration in the intergenerational project. | Ernest recognized the global nature of environmental issues and the importance of local actions. | Miguel recognized the global nature of environmental issues and the importance of local actions. | Ingrid was focused on local issues related to her town and felt she didn't have much to offer on projects outside her community. |
| (3) *Prior connections to nature and enjoyment of the outdoors promoted positive engagement in conservation fieldwork performances*. | Ernest and Walter had extensive childhood experiences in nature that helped to develop their competence in conservation science performances and led them to seek out engagement with conservation field work | Miguel had childhood experiences in nature that helped develop his competence in conservation science performances. Julie enjoyed hiking and being outside. Julie was introduced to hiking in high school | Ingrid enjoyed hiking and camping with her family.<br>Keith and Andy had a history of engaging in indoor STEM experiences related to computer programming and robotics. They did not relate any experiences with outdoor activities and were unaccustomed to hiking or spending time in nature. |

attempt to record all the living species within a designated area - at his school and implementing a junior scientist component where students could work alongside scientists collecting and identifying all the living things at the school in one day. Ernest emphasized two themes of being a mentor that were most important for him, engaging his students in the practices of science and helping them get connected to the community of scientists:

> I'm just tryin' to keep with Warren until he's fully connected. This is an opportunity, 'cause I know [Dr. W.'s] interested in him. I know Walter has worked hard to get his grades. If this is another [university] connection, the more people that know about Walter, the better it is, but it's also—it's a great project and program.

Ernest had been mentoring Walter since the 7th grade when they decided to participate in the ICP program. Ernest's competence in conservation science underscored his ability to mentor Walter and facilitated a successful intergenerational project that allowed the pair to translate their competence in conservation science into action and further strengthened their identification with conservation science.

Miguel was knowledgeable about many fields of science having majored in physics and biology, finally settling on anthropology. Miguel's college courses in anthropology showed him the relationship between people and their environment and the importance of healthcare in people's lives:

> The anthropology courses are just essentially introductions in how people interact, the way that they create their own physical built environment but also the cultural environments. The parts that intrigued me the most about what people do, how they survive or how they thrive, is a lot around healthcare.

Through his experiences working in various parts of the country Miguel saw the intersection of public health and conservation science through the impact of natural and man-made disasters:

> I got to travel around the United States and got to visit a lot of—near working class and blue-collar fishing communities and seeing those people that were affected health-wise, cause it's jobs that take heavy tolls on their bodies and their families, but also they're constantly being inundated with natural and manmade disasters.

Miguel was pursuing a master's degree in public health while participating in the ICP program. He had a breadth of academic science knowledge from his degree programs, but little formal education in conservation science. During the project, Miguel was working towards certification in environmental protection with the Coast Guard. His knowledge of the environment came indirectly from other fields or from informal educational experiences and he learned a lot about nature during his childhood from time spent outdoors in the southwestern U.S. and Mexico with his grandfather and great uncle.

Miguel did not have a lot of experience mentoring students but had assisted students with field projects while a director of admissions and enrollment for a study away program. While participating in the ICP program, he was working at a non-profit mentoring and providing support to first generation college students. Although mentoring was part of his job at the college access nonprofit, it was a type of formal mentoring – helping with college access and retention. Miguel's comfort level with conservation science concepts and mentoring facilitated a positive collaborative experience for him and Julie in the ICP program. They felt they learned, participated, and contributed to conservation science thus strengthening their conservation science identities.

Ingrid had bachelor's and master's degrees in mechanical engineering. She developed competence in science and engineering through her love of cars and hands-on learning. While Ingrid ended up in a STEM field, she hadn't thought of herself as a science kind of person when she was younger, "I probably was not originally much of a science person in high school or anything … I wasn't even much of a math person. I was always a very applied person." Her interest in cars and engineering overcame the negative recognition she received for being a woman who wanted to work in a "man's" field. Ingrid's background, however, did not include coursework or experiences in conservation science. She recognized her competence in physical science, engineering and technology but not conservation science. When the teens wanted to do a project on water quality of the nearby river, she didn't feel she knew enough about it to guide the teens and started looking for resources that could help them conduct an investigation.

> They were interested in doing something along the [river], looking for pollution or doing water quality testing. Then we were looking for possible—some kind of guide, because I'm not a conservationist. I do have some technical background… Engineering is my degree, and I'm interested in conservation, but I don't have any real experience or knowledge about natural conservation stuff.

Keith, Andy, and Ingrid had difficulties deciding on their project. Keith said they finally decided on the microplastics project because they couldn't come up with anything better and felt they could complete it in a short amount of time, "Well, I mean, the whole—the reason we—we couldn't really come up with much else, so why we chose this specific—we were just brainstorming, this seemed like the most feasible project choice, back then."

Ingrid didn't have experiences participating in this field. She felt her lack of competence was a challenge in the program and that she wasn't a good mentor for the two teens because of it:

> I guess this is where I feel bad about having signed up for being their mentor, because I don't have the background in the conservation. That's what I think one of the things that I wanted to bring out at this meeting right now, or to say: that maybe it's better to set up—when you set up a mentorship, to do it with someone who has that background, has ideas in mind.

While Ingrid entered the program with a strong identification with STEM, specifically in engineering, she felt she didn't know enough about conservation science to take on the role of mentor to two teens. Her lack of confidence in her own competence led to difficulties in making decisions about the nature of their intergenerational project delaying the start of their collaboration.

Ernest, Miguel, and Ingrid were all interested in conservation science and mentoring. Ernest entered the program with an already established identity as a mentor and as an environmental educator. Miguel entered the program as a novice mentor but confident that his knowledge of conservation science was sufficient to guide three teens in developing their project. Ingrid's perceived lack of competence in conservation science created difficulties for her to feel that she could guide two teens in making decisions about a conservation project.

**Finding 2: Adult Understanding of Connections of Global Environmental Issues to Local Communities Facilitated Collaboration in the Intergenerational Project.** All participants entered the program with concerns about the state of the environment and wanted to do a project that would make a difference in their communities. However, none of the participants lived in the same town. Ernest and Miguel recognized the global nature of environmental issues and the importance of local actions. They were able to focus their projects in the teen's community while recognizing the issues as relevant to any community. Ingrid was focused on local issues related to her town and felt she didn't have much to offer on projects outside her community. Her team eventually focused on a river close to the three towns, but had trouble making connections to the communities.

Ernest was concerned about the collapse of the biosphere and that most people are unaware of the relationships between global warming, ocean acidification, declining species and the increase of pest species:

> [W]e're really concerned about this world that it's looking like the biosphere may be collapsing. We're in it right now and people don't realize it. It's one of those things where you don't realize how bad it is until it's too late. If you look at all—really, you look at how birds, what's happening with birds worldwide. The good ones are declining rapidly. The monarch population collapsed by 60 percent last year and it already collapsed by 50 percent the year—we're talking 60 percent of the remaining 50 percent and you see this in the ocean is acidifying. Significantly acidifying and the base of the food chain is a plankton and that's based on calcium based on the shells. They're seeing now the erosional features. They're thinning out. Scientists can say well, in 20 years we're gonna lose a lot of this. Coral reefs- more than half are dead. We're talking you look at any clade [evolutionary group of organisms] or whatever, anything. You will see it's in decline except for those species that have adapted to humans, the pests, the insect pests that are evolving resistance to different pesticides. We make new pesticides. We dump more of it and now we're losing—that's partly impacting the world biodiversity of insects. The population keeps going up.

Ernest demonstrated an in-depth understanding of the interrelatedness of different species and earth systems. He connected the biosphere (e.g. birds, insects, plankton, coral reefs and invasive species) to the atmosphere and hydrosphere (e.g. ocean acidification) and human activities. The collapse of the biosphere is a global phenomenon that requires local action. Ernest would have been happy to implement their biodiversity awareness project in any community.

Miguel valued preserving natural spaces in urban environments primarily as a public health issue. Spending time in nature is healthy for people, but green spaces also act as buffers against climate change, providing some level of protection against natural disasters such as flooding. Miguel used his public health lens in their green space awareness project to focus on how preservation of green spaces helps urban communities and specifically low-income community members. Miguel viewed accessibility of information as the first step to getting people to care and protect natural resources in their community:

> and I know I keep using that word accessible, but trying to make those topics so that people can understand them I think will then lead into people caring about it, valuing it, and then understanding the reason why we need to protect the resources that we have.

He quoted a professor who summed up his belief in protecting natural areas:

> One of my favorite colleagues and mentors, she was a marine ecology—or she is, rather, a marine policy professor. She would always begin—first day of her lecture for each semester—by saying, "We protect what we value, and we value what we understand."

People need to know places to value them and want to protect them. Miguel emphasized that "what we understand" is the specific place, not necessarily the scientific reasons why the place is ecologically important. Miguel connected accessibility and engagement with caring and action:

> But to be able to see those connections to accessibility, but also using that as a way to really engage people and, again, let them know—it's like your ideas are valid. We wanna hear your thoughts 'cause at the end of the day, this is a—"this" being any project, really, but large topics like conservation or climate change and health. It's a process that we're all a part of, and if you don't feel like you're a part of the process, you're not gonna care, and if you're not gonna care, then it doesn't matter if the planet's warming up at a record rate or if streets are flooding or if trees are dying.

His view of the importance of green spaces in urban areas was global–affecting all urban communities–while the focus of the project was local (i.e., Julie's community).

Ingrid was interested in conservation work, but seemed more interested in improving her community. She saw her community as having less resources for students than nearby communities such as those of Keith and Andy. She wanted to help the students in her community have research experiences such as ICP that they were not getting through their schools:

> Yeah, yeah. It's like, "Oh, man, how do we help the kids in this community because they need it." They need some additional support because they're already lacking a lot of the resources that are available in other communities.

Ingrid believed her community would benefit from a conservation project that involved her community's youth:

> I think it's a great opportunity for kids in [my town] because [my town] is a community that is very racially isolated. The school systems are very racially isolated. I don't think the kids had as many opportunities as kids in [Keith's town] and [Andy's town] get. I was hoping actually to get connected with a student in [my town].

With her two partners from different towns, Ingrid saw difficulties in deciding on a project relevant to all three communities. She felt she wasn't bringing conservation expertise to the table but would have been able to use her town connections if they were all from the same town and designing a project for that town:

> I was not familiar with conservation issues and ideas and things that were going on around their communities. I didn't have any connections in their communities. I didn't have anybody I could really reach out to very easily. That was I think a difficulty.

Ingrid came to the workshop with a number of project ideas that would benefit her community. Andy and Keith didn't seem interested in those ideas:

> For brainstorming, we didn't have any—even after the program was completed, and we didn't really know what project we were going to do, so Ingrid gave us a few options. We didn't really know if we wanted to do those [Andy].

The partners struggled to come up with a project they all agreed on. The focus on the project's local aspects of the project kept the partners from seeing the global nature of environmental problems that affect all communities.

The ability of the adults in each of the first two cases to see the global nature of environmental problems and translate them to local communities facilitated successful collaboration between the adult and teens. For these two cases it did not matter that they lived in different communities. The issues of declining biodiversity and lack of green spaces in urban areas affects us all. They both had an outlook that started with the global and then brought it to the local level. In the third case, the adult was working on the local level without seeing the global nature of environmental issues such as microplastics. While the partners decided on studying microplastics in a river close to each community, they didn't make connections of how the global nature of any type of water pollution affects local communities.

**Finding 3: Prior Connections to Nature and Enjoyment of the Outdoors Promoted Positive Engagement in Conservation Fieldwork Performances**. Ernest, Walter, and Miguel all had extensive childhood experiences in nature that helped to develop their competence in conservation science performances and led them to seek out engagement with conservation field work. Julie and Ingrid related few childhood experiences in nature, but both enjoyed hiking and being outside. Julie was introduced to hiking in high school and Ingrid hiked and camped with her family. Keith and Andy had a history of engaging in indoor STEM experiences related to computer programming and robotics. They did not relate any experiences with outdoor activities and were unaccustomed to hiking, or spending time in nature.

Ernest spent a lot of time in the woods and wetlands after his mother passed away, “I spent a lot of my youth in the woods, so I learned a lotta stuff.” He related the important role it played in his mental health, “I grew up livin’ in the woods for my wholeness. I don’t know. I just prefer to experience life in the real world.” Being in nature helped him heal and he felt he learned a lot through experiencing the “real world.”

Walter began his love of nature with an interest in bugs and snakes. His parents encouraged his interest by taking him for walks in the woods, talking with him about animals and allowing him to keep various animals in his home:

> Then my parents helped out with that. My dad, he really liked animals too, so whenever we went out on the trails, I would go hunting for lizards. He would help me look for snakes and frogs and stuff. We would talk about them… My dad helped me out with that when I was younger. Then my mom took over, especially with my first praying mantis that I kept. She was my real advocate for keeping it, ‘cause she saw that it was really intelligent for an insect. She also helped convince my dad to let me get other insect species. She's been supporting me for a while.

Walter’s early interest in walking around in the woods and finding animals led him to want to collect and observe insects. The encouragement he received from his parents allowing him to keep insects in their home, deepened his interest and competence leading him to want to devote more of his time to reading and learning about insects developing even more competence in insect ecology.

Walter and Ernest shared a love of nature and being out in the woods. They understood the nature of field work and enjoyed participating in it. Their prior outdoor experiences enabled them to easily decide on a project where they would engage in field work collecting biodiversity data and mapping an urban park close to where Walter lived.

Miguel grew up in the southwest U.S. with his grandfather, but spent summers on his great uncle's ranch in Mexico where he spent a lot of time outdoors interacting with animals and the environment in general. His family used urban green spaces, rural agricultural land, and the woods to teach him about the natural world:

> my grandfather, who was the one who raised me growing up was—he worked in the parks and recreation department for [city], so he was always telling us cool things and like, here's this cool park. He would take us, and we'd go run around in the parks and stuff.

Miguel spent summers working on the ranch in Mexico, but his great uncle also incorporated nature learning during downtime:

> He [great uncle] was very big into taking us around whenever there was some downtime between work and being like, "This is a well. This is why it's okay to drink from this. Here's a plant that you could use for the following purpose." There was a lot of people in my life who encouraged that and gave me general good tips to survive out in the woods.

Miguel was also influenced by his cousins who enjoyed being outside and included him in their play, "Once I found the two cousins that really enjoyed being outside, we were just always outside."

Julie did not share any specific outdoor activities she engaged in as a child, but she related stories about how she visited different local places with her father who was interested in the history of the area. She often visited the arboretum, the local beach and a nearby fort prior to mapping them in the project. Julie joined a number of clubs at her school that related to the environment including the hiking club which influenced her attitude towards hiking:

> I'm in a hiking club at my school, I'm in the Three Rivers United Environmentalist Club, and the new club that's actually starting this week is, Three Rivers Aquatic Activist. So, we'll see what that's in store for that. Yeah. We do lots of fun things. I've gotten into hiking because of the Trail Blazers club.

Julie remembered one positive experience in elementary school science when she got to go out on trails during a field trip to a Native American museum:

> Yeah, I guess I liked going out in the trails. My school took us to the [Museum], and they have trails somewhere in the back, so I guess you can say that was environmental, but we were just there to look at—actually, we were there to look at trees, now that I think about it, but that was the only time.

Julie hadn't thought about the field trip in environmental terms until she remembered they went on the trails to look at the trees. She didn't equate just being out in nature with being environmental unless there was a specific purpose related to learning about the environment.

Miguel's prior outdoor experiences in nature and Julie's knowledge of her community facilitated their decision to create an awareness campaign of green spaces in Julie's town. Both partners enjoyed spending time outside and hiking. They were happy to hike around the different green space locations in the community mapping points of interest.

Ingrid did not relate childhood experiences related to nature outside of wanting to be a forest ranger from reading *Ranger Rick* magazine. Her passion growing up was cars. Ingrid sought out opportunities to work on cars, which was unusual for women and girls at that time (late 70s early 80s). She took an auto shop course in high school which sparked her interest in engineering and technology:

> Actually, when I was in high school, I took an interest to cars, and I took an auto shop class. I got a job at a gas station *[laughter]*. I worked for Sears for a number of years in

> their automotive division.

Ingrid developed competence in science and engineering through her love of cars and hands-on learning. She related how she was a member of a hiking club and enjoyed hiking and camping with her family and being in nature.

Andy's childhood experiences in science revolved around reading books about science and participating in various STEM-themed clubs, "In our school, we have the science Olympiad, so we had this contest… Yeah. I'm in different events. I'm in chemistry lab and the protein modeling, as well." Andy was also involved in science bowl at his high school. He considered himself a techie having participated in computer programming and robotics programs since elementary school:

> In elementary school, I would go to these programming outreach programs by high schoolers, and I would participate in those. I was an elementary student who would just learn how to code. I was also attending these robotics programs where, again, the high schoolers would be the ones that organized events. We would go there, and they would teach us about robotics.

Andy had been involved in a lot of out-of-school STEM experiences including an afterschool program in the town library on coding, but no outdoor experiences like hiking or canoeing.

Keith did not relate any outdoor experiences. In school, he was active in the robotics club. He considered himself more of an engineering kind of a person, "I'm just more of like an engineering science kind of guy." Keith also considered himself a techie meaning that he, "plays with computers. Does stuff on computers. Maybe programming, or hacking, or does troubleshooting. Tech support *[Laughs.]"* He assured me he had never hacked anyone. He also assisted others with technology, "Yeah, I use technology a lot. Sometimes I find myself helping teachers with their SMART Boards and stuff." His extracurricular activities involved technology and engineering (e.g. robotics).

When engaged in field work, the teens' lack of outdoor experiences created challenges in the project. They were uncomfortable walking in the woods due to concerns about ticks and didn't want to go through thick brush to collect samples from the riverbanks. Due to the difficulty accessing the river from land, they decided to canoe down the river and access sites that way. Andy, however, could not swim so his parents did not give him permission to go on that sample collecting trip. While Keith said he was excited to do field work, the reality of hiking through brush or paddling down the river was not what he expected. He described finding sites to get data in the field as annoying and thought he preferred working in a lab which he found easier and more controlled:

> I'm fine either way but, honestly, I prefer sticking to the lab just cuz it's a lot easier. How do I put this? … Just we don't have to get dirty. Once we have all the data, we can just analyze it… It was just annoying, to some extent, just cuz we couldn't find any good sites. We would just keep on going.

Ingrid didn't see the teens as interested in nature, or enjoying time outdoors engaging in conservation work:

> Neither of them are real—they're not real outdoorsy kinds of kids. They're just not. Getting in the water, things like that were really foreign to them. That was difficult. Yeah, I guess I was thinking that the kids would be more enthusiastic. I don't know why they signed up for this program when they really weren't interested. I don't think they were all that interested in natural conservation issues.

Field work is a large component of conservation work. Walter and Ernest were already heavily involved in field work through their history of participation in environmental clubs and groups. Miguel and Julie both enjoyed being outside, hiking and exploring different local places. Conducting field work was enjoyable for both of them. Ingrid also enjoyed hiking and canoeing and enjoyed the outdoor aspect of field work. Andy and Keith, however, had not had experiences hiking, canoeing or exploring outdoors. Andy was unable to participate in the major data collection trip due to his inability to swim. The reality of field work was not pleasant for Keith who realized he much preferred the controlled environment of the laboratory.

These aspects of the participants' historical STEM identities (i.e., adult self-recognition of competence in conservation science, the ability to connect global environmental issues to local communities, and prior enjoyment of outdoor experiences and were found to promote successful collaboration of intergenerational partnerships providing opportunities for further development and strengthening of the participants' identification with conservation science. This is shown in figure one as important aspects of the historical STEM identities of the participants that they bring to the collaborative partnership. I now discuss findings of how different aspects of participation in intergenerational partnerships promoted or hindered further development of the participants' conservation science and technology identities.

***Aspects of Intergenerational Partnerships that Promoted Identification in Conservation Science and Technology.***

Participation in the intergenerational projects provided opportunities and experiences that may have strengthened the participants' identification with conservation science and technology. All the participants entered the program identifying with a STEM field. Ernest, Walter, and Julie identified with conservation science. Ingrid, Keith, and Andy identified with engineering. Andy and Keith also identified strongly with technology in the form of computer science, and Miguel identified with all of these fields. The first four findings about the participants' program experiences relate to the constructs previously identified as important to the development of a

STEM identity (i.e., competence, performance and recognition). These were: (1) opportunities to use and share knowledge of conservation science, (2) opportunities to engage in performances of science and technology practices to complete a long-term project, (3) recognition and incorporation of participant resources into the collaborative project, and (4) recognition by the larger community (Table 2). The last three findings relate to social structures evident in the intergenerational partnerships: (1) development of a relationship with effective two- or three-way communication to learn from and/or with each other, (2) adult promotion of student voice and corresponding student agency, (3) seeing the program goals as aligning with personal or career goals.

**Finding 4: Collaborative Intergenerational Partnerships Promoted Further Development and Maintenance of STEM Identities by Providing a Platform for Demonstration of Competence in Conservation Science.** Participants in the three cases were able to demonstrate their competence in conservation science and technology through the completion of their year-long project and subsequent presentation at a land trust conference. For Ernest and Walter, and Julie and Miguel, using and sharing knowledge through their conservation projects was more important than learning new content. The focus for Ingrid's, Keith's, and Andy's project was to generate and disseminate new information about the distribution of microplastics.

Developing competence in conservation science was not a priority for Walter and Ernest in their project. They felt their individual knowledge complemented each other and together they were competent in their knowledge of the natural world. Walter had a high level of competence in knowledge and understanding of insects, especially beetles. Ernest's background with a degree in natural resources and experience as a naturalist and science teacher developed his competence in many fields of conservation science but especially in botany. Ernest and Walter used their

*Table 2: STEM Identity Constructs Important in Intergenerational Partnerships*

| Findings: | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| *(4) Collaborative Intergenerational Partnerships Promoted Further Development and Maintenance of STEM Identities by Providing a Platform for Demonstration of Competence in Conservation Science* | Able to quickly decide on their community project by starting with an issue where they already knew enough to feel competent designing a project. Focused on communicating the issue to the general public. Communicating their knowledge reinforced their conservation science identities as people who know about, use, and contribute to science. | | Needed to learn about microplastics. Ingrid did extensive background research. Keith and Andy did not and were unable to demonstrate their competence which might have negatively affected their identification with conservation science. |
| *(5) Engaging in Performances Necessary to Complete a Long-term Project was Important for Maintaining and Strengthening the Participants' STEM Identities.* | Both partners engaged in performances together (e.g., digital mapping, identifying insects, plants, and other wildlife, communicating) | Both partners engaged in performances together (e.g., observing, justifying and communicating) | Ingrid engaged in online research, sampling, and all technology performances. Keith and Andy engaged minimally in performances throughout project |
| *(6) Recognizing and utilizing the resources each participant brought to the project was important for successful collaboration and promotion of STEM identities.* | Based their project on recognition of their combined knowledge of plants and insects. Discovered other strengths through their collaboration. | Discovered each other's unique resources. Recognized how these resources could be used in their green space awareness project. | Did not recognize each partner's resources as valuable in this project and they were not incorporated. |
| *(7) Positive recognition from meaningful others was important for strengthening the STEM identities of adults and teens.* | Both partners felt recognized by larger conservation community | Miguel felt recognized by Julie and her community. Julie felt recognized by ICP scientists | Partners did not feel recognized by family, friends or conservation community, |

knowledge of insects and plants to investigate the biodiversity of a local urban park. The project was not designed to increase their knowledge, but instead to work as a platform where they could engage the public in learning about biodiversity. For Ernest and Walter, the collaborative project was a way to put their competence into action. In this way, Ernest and Walter were able to reinforce their identities as people who understand, use, and contribute to conservation science.

Julie and Miguel were able to demonstrate their knowledge of the importance of green spaces through their collaborative project. Julie understood that green spaces are important in an urban area for carbon sequestration and groundwater filtering. She understood the consequences of air pollution in urban areas without a lot of green spaces:

> Because if you look at Los Angeles, there's like just skyscrapers, and buildings, and filming studios. Why do they have smog all day? Because they have no trees to filter out the air or anything like that. In a place where there's lots of people and not a lot of green spaces, you get a lot of dirty air, and stuff. Just things like that.

The role of trees in carbon sequestration, air and water filtering is not something she learned in the ICP project, but the project gave her an opportunity to contribute to conservation science by communicating these understandings that she feels are so important for everyone to know.

Through the collaborative project Miguel was able to combine his understanding of green spaces with his knowledge of what impacts mental and physical health. He evinced a more nuanced understanding when he connected the importance of green spaces to climate change issues that will impact coastal cities like this urban community. In thinking about how to promote green spaces, Miguel connected scientific competences he had in various fields. He was able to tie together his knowledge of ecology and wildlife conservation, coastal restoration, sea level rise and public health in their green space awareness project:

> Then the one that was harder to make the jump with was the ties between green space conservation and ecological restoration and sea level rise, and the importance of using those as riparian buffers and systems to sort of keep shorelines intact… my own academic interest is coastal restoration as a means of—and again, this is where I said

> earlier, it's as a means of natural riparian buffer systems to help in flood-prone areas, which has a great effect on the physical and mental health of people living within those areas.

Miguel's participation in the collaborative project did not develop new knowledge in conservation science but allowed him to contribute to the field by demonstrating the connections between different fields of science and communicating the importance of those connections to the community.

Miguel and Julie strengthened their identities as individuals who are capable of understanding, using, and contributing to conservation science through the demonstration of competence in their green space awareness project.

The focus of Keith's, Andy's, and Ingrid's project was to learn about the presence, distribution, and harmful effects of microplastics in the environment and generate new knowledge through their investigation. While the three partners each engaged in some level of background research, only Ingrid demonstrated acquiring new knowledge that way. Ingrid felt she had learned a great deal from her background research. She learned how microplastics enter an ecosystem in a variety of ways from laundry to cleaning paint supplies, and the wear and tear of road tires:

> Some of the interesting things that I learned about microplastics are some of the sources of microplastics, like laundry. That was something that just I never really thought about, the fact that so much of our clothes are made of plastic nowaday… Do you know paint is an issue? … I never thought about that. Rinsing off your paint brushes and stuff, acrylic paint, after you paint your living room or something and you rinse off your paint brushes in the sink. All that's plastic. It's liquid plastic. Isn't that gross?... The other thing that I thought was very interesting is what a big impact car tires have, because as our car tires

> wear down, all that rubber is going somewhere… It's all going on the roads, and it's all going into the storm water systems and into the rivers and stuff. That was interesting. That's just the reading that I did about the subject.

She also learned about the difficulties of sampling and identifying microplastics:

> I mean even just to filter water to that level, to that size, how much water do you have to filter. They're talking about discharge, like from the wastewater treatment plant you would have a discharge, and you might find like 1.5 fibers per liter of water, so how much water do you have to sample? Then to get something, and then go through this filter and try to find these microscopic pieces, and then try to identify them if—you know, are they plastics, are they something else. It gave me an appreciation for how complex it really is to investigate that, to find out the sources and...

Keith and Andy understood that plastics in the environment were an issue because they get into animals and humans and harm them:

> Maybe the environmental effects of plastic. Maybe knowing how plastics get into animals and stuff. How that hurts them and stuff like that … Plastics are a growing problem in modern society. Just it has relevance, too. [Andy]
>
> Well, plastics have earth-significant effect on wildlife. Ingesting them can be fatal, because plastics aren't natural and so they're made out of artificial chemicals and stuff. So, when animals eat them, they don't—it doesn't end up very well for them... Well, I mean, it can get into our drinking supply. Our water supply and stuff and hurt people too. [Keith]

Andy wanted to research microplastics because, "it was a hot topic that was in environmental science." He approached the research as a problem to be solved – like an engineer:

> The problem that we were tryin' to solve was that, there have been studies where in

> fresh waters, there were a lot of plastics that were being thrown into the rivers, and these actually harm the wildlife and the different organisms in the water, as well.

Having conducted background research about microplastics, Andy saw their project as determining if this problem was in their local river system. He viewed it as a first step in microplastic research to determine if they are present. Then they could determine if more research needed to be done:

> We wanted to know if our local river would have this problem, as well. That's why we decided to do this, and check if there are any plastics. Does it have any impact on—will it have any impact on the organisms? Does there need to be any more research done?

Keith and Andy were only able to give general facts about plastics being harmful to wildlife and humans. Andy did not demonstrate any additional learning about microplastics prior to the conference. He did not participate in the last interview after the conference so I cannot determine what he learned overall. Keith stated how he hadn't learned much conservation science by doing the microplastic project. Although he was surprised by the existence of plastics in the river close to his home, "Hasn't really changed my viewpoint that much. I already knew that there was plenty of plastic out in the oceans and all, and it was kind of shocking to see it in our own backyard, but." Participating in the ICP program provided an opportunity for Keith, Andy, and Ingrid to learn about the issue of microplastics in the environment and conservation science in general and possibly create new understandings about microplastics. Of the three, only Ingrid demonstrated an increase in her knowledge, and that was accomplished through background research.

In the first two cases, the partners were able to quickly decide on their community project by starting with an issue where they already knew enough to feel competent designing a project. Walter and Ernest focused on the issue of declining biodiversity, and Julie and Miguel chose the issue of green spaces in urban communities. Both partnerships focused on communicating the issue to the general public. Communicating their knowledge reinforced their conservation science identities as people who know about, use, and contribute to science. The first two cases did not have to spend time trying to understand the causes of the problem or how to study it, they were able to start collecting data soon after the workshop. The third case needed to spend time trying to understand the causes of microplastics–how they enter waterways–and how they can be sampled in freshwater bodies. The adult, Ingrid, was willing to invest this time up front and did extensive background research. The two teens did not, perhaps because they were already busy with schoolwork and other afterschool commitments. By not having sufficient background knowledge on their project's focus, and time or willingness to learn more before starting the data collection phase, the teens were left open to negative recognition such as they encountered with the watershed association scientist. The scientist tried to explain to Andy and Keith why smaller sediments are found where water moves more slowly. This was in relation to where they should sample for microplastics which are small and light:

> Scientist: Do you guys remember in grade school or something where someone would take a jar of water that had big rocks and little rocks and sand and silt, and mud and they'd sort of stir it up and then watch it settle out. Did you ever do that?
>
> Keith: Not at all [Andy squirmed in his seat and nodded no while smiling]

The discussion continued with the scientist asking the teens to determine which size particles would settle out in a fast-moving stream:

> Scientist: Ok so, different things will, if you go into a brook where it's really steep way up in the headwaters and the water is just pouring, pouring down, what size rocks or sand or mud or are you going to see there?
>
> Keith: waterfall?

Scientist: waterfall, lots of water pouring down

Keith: small ones

Scientist: big ones

When Keith responded incorrectly, the scientist immediately corrected him and continued explaining about the energy needed to carry large boulders. This was another instance of negative recognition of the teens' competence in this area. The scientist asked one more question of the teens at the end of explaining about how the speed of the stream affects how far sediments will travel:

Scientist: Do you know what mica is? The mineral mica?

Teens: barely shake heads no

Scientist: It's like – you guys gotta come hiking [laughter]

This time the teens were very hesitant to answer since they didn't know what mica was. The scientist tried to make a joke about how they don't spend much time outside, but she was negatively recognizing their competence again. The teens were unable to demonstrate their competence on the issue of microplastics which might have negatively affected their identification with conservation science.

**Finding 5: Engaging in Performances Necessary to Complete a Long-term Project was Important for Maintaining and Strengthening the Participants' STEM Identities.** During their collaborative project, the participants engaged in a variety of science and technology performances which provided an opportunity for them to demonstrate different competences and be recognized by others. The intergenerational partnerships engaged in performances of practices such as identifying, sampling, analyzing, digitally mapping, problem-solving, justifying, legitimating, and communicating to complete their projects.

Ernest and Walter's project involved creating an interactive trail map showing the biodiversity of an urban park located close to where Walter lives. The partners used an app called Track Kit that maps an area by putting down digital breadcrumbs as you walk a trail. Walter appreciated learning these technology skills through an authentic community-based project. He explained how he had learned a little bit about mapping for an environmental science class his freshman year, but that learning how to use it for a real purpose in this project was more valuable:

> Using Track Kit, learning how to map, that was important. I had a little bit of experience with topographic mapping from my environmental science course in freshman year. It's really good to know how to use it more, especially in a real role, in this group project. That was helpful.

An essential part of Walter's and Ernest's project involved identifying the plants and animals in the park. Walter was in charge of identifying insects and Ernest identified everything else (plants, fungi, and vertebrate animals). The intergenerational project provided a space for Walter to engage in identification performances that he had already learned in relation to insects, and also allowed him to learn and implement new strategies for identifying plants and other animals. At the same time, it provided an opportunity for Ernest to teach Walter about identification practices establishing himself as an expert naturalist–one who is knowledgeable about identifying trees and wildlife–and Walter as still a novice learner in these areas. This correlated with their already established roles of mentor/mentee.

While the intergenerational partnership helped Walter and Ernest learn how to create digital maps, it also provided a venue for Walter to demonstrate his problem-solving skills with computer issues. Walter explained that Ernest was familiar with the basic function of Power point but had difficulties using the poster template that required sizing the text to put into frames. Walter was accustomed to using Google Docs when collaborating with other students on projects. He used Google Docs in this project to create lists of species and was then able to highlight sections and put comments on areas that needed to be revised. Since Ernest was not comfortable with Google Docs, Walter shared the information with him by downloading it as a word document.

Walter and Ernest engaged in communication performances including informal conversations between the partners around the project as well as the creation of a presentation poster, and formal presentation to conservation organizations. Walter related that he enjoyed the poster presentation and the opportunity to talk with people about his project:

> Presenting? It was interesting for me. I'm used to that since it's not a full-on presentation one-on-one. It was more people walk around and talk to us. I'm used to that because I used to do the STEM family nights where I bring in insects and talk to the public about them, and it'll just be groups of people walking by, just asking questions about them.

The inclusion of a poster presentation session at a land trust conference was an opportunity for the intergenerational pair to demonstrate and refine various communication practices related to their scientific research. The poster presentation afforded Walter another opportunity to communicate to others his passion for the natural world and especially beetles. Through this performance, Walter was able to demonstrate his competence in natural science with the larger conservation community and be recognized by others in the field. Ernest felt presenting their research to the larger conservation community was important to help Walter make connections to further his college and career goals:

> Being at [university] and meeting all these different people and you felt more connected. It's almost like you're part of this collegial group. Socialization especially for a high school kid, getting that goin' at this stage it just broadens their horizons and

raises their expectations for themselves I think.

While none of these performances with the exception of learning how to use the geospatial apps were new, Walter expressed the importance for him of seeing a large project like this through to the end, “Then, it was also great to learn how to complete a project like that since I haven't really done anything that large of a scale before. Yeah. It was great to do that.” Walter measured the success of the project as the completion of the poster for the conference. Creating the poster, is a performance and also the culmination of all the performances undertaken in the project, “The fact that I got the poster done on time. We got a good amount of species for our list because I wasn't sure if we would be able to get as many species as he wanted for the list.” Walter and Ernest’s engagement in conservation science, technology, problem-solving and communication performances further strengthened their identification with conservation science by providing opportunities for the partners to be recognized by the larger community for their ability to understand, use, and contribute to conservation science.

Julie and Miguel engaged in the science and technology performances of observing, digital mapping, justifying, and communicating. When Julie and Miguel hiked the different locations for their informational brochure, they used Track Kit to create a digital map of green spaces in their community. This involved observing and identifying points of interest at each location. After tracking the paths, Miguel took responsibility for uploading the information to Google Maps to create an interactive map accessible to the public. After encountering difficulties with uploading– as had many other participants - he consulted the Google forum set up by the ICP program coordinators. He didn’t find anything helpful, and eventually figured out a work around, “It just would’ve been nice if we could have the Track Kit transfer over to Google Maps. Instead, I just ended up comparing maps and doing my best plotted points. It ended up working in the end.” Julie used Track Kit to map the different locations but left the rest of the technology components of the project to Miguel. Learning how to use technology was not as important to Julie as communicating her knowledge of green spaces through the written brochures. Julie felt creating the written portions of the pamphlet was her biggest contribution to the project:

> Yeah, definitely the write-ups for the pamphlet, 'cause I had to write about each park, and an introduction, and such like that, so definitely the writing, which is a big part of it, I guess, the pamphlet, since that's our main thing is making the pamphlets available to everyone.

Julie and Miguel used the pamphlets as a vehicle to communicate scientific information about the importance of green spaces in urban communities to the general public. This involved the epistemic practice of justifying scientific claims. They made the claim that green spaces are important and provided four main reasons why. Green spaces provide: (1) locations for recreation and leisure, (2) habitats for animals, (3) aesthetics and town beautification and (4) health benefits with places to walk, jog and explore. Miguel considered communication about the importance of conservation science as important as engaging in conservation work itself:

> What I think I've been hitting more on or learning more from is the very specific section of conservation that has to do with communication of a topic… But to a common, generalized population, why should they care about that?

Julie and Miguel felt they were contributing to conservation science through the creation of their green space brochure with interactive map. The performances they engaged in during their project were essential to creating the brochure and for making it available to everyone in Julie's community. Contributing to science is a main component of developing or strengthening a person's STEM identity. While Julie used Track Kit initially to map the green spaces, she didn't continue to use or learn more about the technology. She felt her contribution was strictly in conservation science. Miguel continued to learn more about how to use geospatial technologies to contribute to conservation science, thus strengthening both his conservation science and technology identities.

Keith, Andy, and Ingrid engaged in investigative practices (e.g., online research, site selection, sample collection, sample analysis), technology practices (e.g., using cell phones to collect data with Track Kit, uploading to Google Maps, and using Google Docs and Power point) and communicative practices with each other and with the larger conservation community. Finding a common time for the partners to engage in these practices was a challenge throughout the project and the partners often worked separately or in pairs rather than all three together.

Ingrid seemed more engaged in the practices than either of the two teens. She did the majority of the background research on sampling and analyzing protocols. While Ingrid thought Keith had also looked up information on microplastics, she was the only one who discussed what she had learned from her research. Ingrid shared different ways microplastics enter freshwater bodies and different sampling protocols - most of which needed high-end equipment they didn't have. The partners decided on a simple flotation technique which they acknowledged was not very accurate. During the canoe trip with Keith, she directed the sampling and did most of the actual scooping of sand. Andy did not accompany them, and Keith only did what Ingrid directed him to do.

Andy performed the analysis of the samples. During the meeting with the watershed association scientist, they discussed taking the samples to one of the teens' schools and processing it there or looking at the samples under the microscope. Neither teen followed through on this and the microplastics were identified by the teens without any guidance from someone more knowledgeable about rocks or microplastics. They only asked their parents for ideas of what the particles were. Then they claimed they found plastic particles in the samples.

Keith seemed to know they may not have found plastics, “Then, there was actually—what’s it? - analyzing the samples, to some extent, cuz we never figured out what those things were.”

While collecting samples along the river, the team used Track Kit to create waypoints of sample sites and any other interesting spots to put into an interactive map. The first time the team went out to scout for access points, they all used Track Kit. During the canoe trip, only Ingrid took waypoints, though Keith took pictures on one phone and started Track Kit at the beginning of the trip on another. After collecting the samples and creating waypoints, Ingrid ended up taking responsibility for uploading the data from Track Kit. She had difficulties uploading - which Miguel had also encountered - and used the Google forum to get assistance from other teams. The advice she got didn’t work, but she persevered and eventually figured out a work around. Ingrid’s troubleshooting to make the interactive map from the Track Kit information and separate photos shows a high level of comfort using technology especially considering this was technology she was still learning. In the end she was able to get their track uploaded to Google Maps. Andy and Keith did not learn how to upload the Track Kit information or how the information was displayed on a Google map. They were unable to interpret the interactive map Ingrid created to find the starting point for the canoe trip.

In this partnership, Ingrid engaged in science and technology performances and felt she had learned a lot about microplastics and geospatial technologies. Ingrid did the majority of the background research to find sampling and analyzing protocols, as well as the physical part of collecting the samples. She performed all of the technology aspects of the project after the initial use of Track Kit on the first outing. This involved troubleshooting to upload the Track Kit data to Google Maps. She did not participate in analyzing the samples and the teens never showed her the samples or what they considered microplastics. She also wasn’t able to meet with the teens and the ICP coordinator to create the presentation poster. Engaging in performances supported

Ingrid's STEM identity as someone who is knowledgeable about and contributes to science, and as someone who is able to use technology in pursuits of consequence. She considered where their research might go in the future:

> Now I have ideas of what might be very interesting things to look at, the discharge of some of these wastewater treatment plants and really looking at the sites we saw where the stream water comes into the [local] River.

She also was considering how their project could be used in the community:

> Yeah. I was thinking of somehow making it available through that kayak company that we used, or the canoe company, but I didn't pursue that any further, but I was gonna suggest that. I mean we could do like one of those barcode things, scanner, where if somebody wanted to follow that map and they were renting from that canoe company, they could—

However, difficulties throughout the project with a lack of communication from the teens and a lack of recognition for her performances by her partners and the larger conservation community may have impacted Ingrid's desire to continue in this work, "Right now, I'm a little tired. I have to get—I've got other obligations and stuff. I'm not going to sign up for it this year, definitely not."

Keith and Andy minimally engaged in performances throughout the project and Keith at least did not feel he had learned much. Keith's lack of engagement in performances did not support his conservation science or technology identities. The partners only engaged in field work on two occasions. The first looking for access points from the road to take samples and the second locating sampling sites by canoe. Andy took charge of analyzing the samples and shared the results with Keith and their parents. The teens had the opportunity to seek out further resources at their schools (e.g., microscopes, and science teacher expertise) to analyze and identify microplastics but chose not to. They ended up relying on the simple protocol that Ingrid found through her research and their own and their parents' interpretation of the results. In the end they were unsure what they found.

The two teens expressed interest in learning more about geospatial technologies, yet they relinquished responsibility for the technology aspects of the project to Ingrid after the initial excursion looking for sampling sites. They did add a bar code to the presentation poster, but since it was from a site with a one-week free trial, it no longer worked at the conference. In the end, Keith did not see himself continuing in this type of work unless it was as an application to another field he was more interested in such as robotics, "Well, I mean, not as a specific career or interest but I could maybe draw parallels between some of my other interests and this like maybe designing robots that would clean up. Yeah." The lack of engagement in the performances necessary to complete this project did not promote the development of a conservation science or technology identity in the two teens.

In the first two cases, the partners engaged together in various performances necessary to complete their long-term project. Engaging in the performances together provided opportunities for the partners to develop their relationships and be recognized by each other for their competences. The performances by the partners established them as individual's who understand, use and can contribute to conservation science strengthening their conservation science identities. In each of these cases, one partner, Walter in the first and Miguel in the second, took on the responsibility for the technology aspects of the project, possibly further strengthening their identification with technology. In the third case, the teens were much less engaged in performances related to the project and when they were, it was mostly not together with the adult. The lack of engagement in performances by the two teens in the third case, missed opportunities for the teens to be recognized for their competences in conservation science and technology. This was especially true in their lack of engagement with the technology aspects of the project, an area where they recognized themselves as competent. By not performing the technology aspects necessary to create the interactive map from the Track Kit data, they did not develop any more competence in geospatial technology which could have strengthened their STEM identities.

**Finding 6: Recognizing and Utilizing the Resources each Participant Brought to the Project was Important for Successful Collaboration and Promotion of STEM Identities.** In each partnership, the teen and adult participants brought different types of knowledge, skills, and life experiences to inform their project. When these resources were recognized as useful for the conservation project, they promoted each participant's self-recognition as someone who contributes to science thus potentially strengthening their STEM identity. Two of the partnerships recognized and incorporated these resources into their projects providing opportunities for each partner to be recognized for their competences and performances. The third partnership recognized some of these resources but did not incorporate them into their project missing an opportunity for recognition that could have strengthened their STEM identities.

Ernest and Walter, already familiar with each other's competences, based their urban biodiversity awareness project on the recognition of their combined knowledge of plants and insects. Ernest recognized Walter for his competence about insects and as a budding expert on beetles. In a meeting with Walter's counselor and STEM coordinator, he shared how Walter had been very successful in a high-level competition, "So, he's making waves with that. He presented at [the large public university] at the [state] entomological society. He won second place - you know there's grad students and everyone else presenting." Ernest also recognized Walter's teaching abilities which related to his competence in communication. Walter recognized

Ernest as the plant and soil expert as well as competent in identification of mammals, “He knows most of the plant stuff and the soils. Then I know a lot of the insect stuff. We both know a lot about [state] wildlife, so mammals.”

The partners started their project with recognized resources but discovered other strengths through their collaboration. Ernest recognized Walter for his writing abilities, and computer skills. Along with recognizing Ernest for his conservation science competence, Walter recognized Ernest for his organizational skills in keeping the two on track with the project, “I think Mr. S is the organizer, because I'm working on organizing different things, but I'm not the best at it. Mr. S helps out a lot with that part.” Recognizing and promoting each other’s resources established clear roles in the partnership facilitating their collaboration of a successful project. The STEM identities of both partners were strengthened when they were able to perform science and technology practices that demonstrated their understandings of conservation science and complete a project they felt contributed to the field.

Julie and Miguel did not know each other prior to participating in the CTP program. They discovered each other’s unique resources through their initial interactions in the workshop and early in their fieldwork. They recognized how these resources could be used in their green space awareness project. Julie had extensive knowledge of her community including existing green spaces and the history of the area. Miguel brought an anthropological lens that combined knowledge of public health, conservation science, and economics.

Mapping trails in Julie’s community gave her the opportunity to share her knowledge of her town. She knew a lot about her community, not just natural resources or green spaces, but also the history of the area. Working on a project in her community was important to Julie. She felt it was especially important since it was an environmental project in an urban area:

It was definitely cool getting to do a project right here in my own town. That wouldn’t

> be something I did through my school, so thank you for having this opportunity… I'd like to mention definitely an environmental science project in a city, you don't see that too often, so it's definitely fun to do.

Miguel frequently recognized Julie's knowledge of her community and her engagement in the community:

> Sure, so you've probably noticed today that one of our team members *[laughing]* is especially knowledgeable of everything. I thought I knew. Again, humbling and inspiring to be with people who obviously know that much information.

Julie recognized Miguel's expertise in public health and technology. She appreciated that Miguel's background was different from hers and recognized his competence in environmental science came from his work in public health:

> Getting to do a project with people who would be strangers and you have all different backgrounds and stuff, and they both know environmental science. He's even in an environmental science career. He's in health and stuff. That's pretty cool getting to see.

She also appreciated Miguel's comfort level with technology and expressed gratitude that he took over and figured out how to upload the Track Kit data to Google Maps, "Miguel had taken up the role of getting the maps done, even though Track Kit didn't work, 'cause then I would've been like, "Oh, I guess we're done." Then he got it done." She didn't think the project would have been completed if the technology parts had been left to her.

Julie and Miguel recognized and used their complementary resources to complete their project. Julie shared her knowledge of the community and Miguel shared his understanding of how green spaces can contribute to mental and physical health. Like Ernest and Walter, the recognition of complementary resources established clear roles in the project facilitating collaboration and resulting in self-recognition of a successful project. Through their collaboration, Julie and Miguel demonstrated they were able to understand conservation science issues, use science concepts and technology practices to contribute to the conservation science community. At the end of the project, Miguel related that he was proud of their accomplishments recognizing his own and Julie's competences in completing their collaborative project:

> I did take some over to the parks and rec department, and I was sharing it with everybody I knew, 'cause at the end of the day, I was, like, "Listen. I'm proud that I did a project like this."

Keith, Andy, and Ingrid were interested in and had developed some level of competence in engineering. Ingrid had an extensive background in automotive mechanics and engineering. Keith and Andy were also involved in computer science and robotics activities. However, the partners did not recognize these resources as valuable in this project and they were not incorporated. Ingrid was aware of Keith's interest in robotics and both teen's interest and competence in computer science. The teens, however, were unaware of Ingrid's background in automotive engineering.

When relating how each team member contributed to the project, the focus was on what each team member did to complete the project and not on the skills or knowledge they brought with them. During the project they did not come to recognize any new resources in each other. Keith acknowledged that all three teammates worked on the project but felt he and Andy split the work in half:

> Well, I mean, [ICP coordinator] has helped us a lot with the project and guiding us through the whole thing. Ingrid, Andy, and I, we've been doing the project, so, that's kind of important… Well mainly, it's just been me and Andy splitting it about half, half, and then Ingrid facilitating anything. I was helping out as necessary.

Keith did credit Ingrid with guiding them through the data collection process. He saw her understanding of the scientific method – controlling for variables in the sampling protocol as being good at organizing:

> Ingrid's really good with helping us organize stuff. She would come up with things like—make sure that our samples and stuff were credible and that we weren't—she had the whole idea of collecting samples that are specifically a square foot, actually establishing control variables during the experimental stuff and stuff like that.

Keith did not recognize Ingrid's contributions outside of organizing. He did not mention the specific ways Ingrid had facilitated the project such as providing transportation, renting the canoe, paddling the canoe, creating the waypoints with Track Kit or ultimately uploading the information and creating the interactive map. Ingrid made a comment about actions showing recognition more than words which seemed to imply their lack of action in the project demonstrated a lack of recognition for what she contributed.

Ingrid recognized the teens as sweet, smart, and technology savvy yet she was the one who performed the more difficult technology aspects of the project. Computer technology was the one area in their project the teens expressed interest and competence. The fact that Ingrid performed the bulk of the technology aspects of the project was a missed opportunity to engage the teens in an area of strength.

Recognizing and using the resources each partner brought to the project allowed each partner to feel they made a unique contribution to the collaborative partnership. It gave each partner ownership of the project. Recognizing each other's resources acted as a starting point to develop their collaborative project, helped to clarify their roles in the project, and promoted relationship building between the partners. Ernest and Walter designed their project based on their recognition of each other's competences in botany and entomology respectively. They each knew which parts of the project were their responsibility and, working together with clear roles made their relationship grow stronger. For Miguel and Julie, the project's focus started from Julie's interest in green spaces, but the partners soon recognized how their unique resources could be used in this project. The partners used Julie's knowledge of her community and job at the recreation department, and Miguel's knowledge of environmental influences on public health to create and disseminate their informational brochures. Through the recognition of each other's resources they recognized each other as equal partners in the project with clear roles and began developing a more long-term relationship. Ingrid, Keith, and Andy struggled to come up with a project they all wanted to do. Ingrid approached the project focused on community needs without an equal focus on the resources each team member brought to the table. The lack of recognition and promotion of each partner's resources missed an opportunity for them to be recognized for the competences they already had and new ones they developed during the project. This lack of recognition and incorporation of each other's strengths created challenges for collaboration among the team members and did not promote their STEM identities.

**Finding 7: Positive Recognition from Meaningful Others was Important for Strengthening the STEM Identities of Adults and Teens.** Positive recognition of a person's competences and performances has been found to be important to developing and maintaining a STEM identity - if that recognition comes from meaningful others. Who is considered meaningful depends on each individual's type of STEM identity. Ernest emphasized that recognition from students and parents was what mattered most to him:

> Well, working with Walter. Working with A.P. before that. Those handful of kids that I associate with and see a little bit of me in them. I get also in school, I have a lot of kids that like my classes, things like that, so that's valuable. Not from my colleagues so much and not from my administrators especially. I get it more from—and parents 'cause when I take the MATHCOUNTS kids to the [University] to compete all day and when I

> take the Science bowl kids to compete, that's—but there's a lot of positive. Those parents love you. They make it known.

Walter acknowledged he liked getting praise for accomplishing difficult projects, "Then it's nice when my parents tell me that I did well on a project or something. It's very nice, especially when it's a project that really took a lot of hard work." Walter didn't focus on the accomplishments or recognition that may follow, he was more interested in doing the actual work in the project:

> I don't really think a lot about the actual accomplishments. I think more about the work that involves going into it. Some of the other projects I want to work on it's more so I'm looking at what has to be done than actual accomplishment itself.

While recognition was important for Walter, he was epistemically motivated to learn about insects and work on conservation projects involving insects. Walter recognized his success in the project as the completion of the presentation poster that was the culmination of everything he and Ernest had done in the project.

Working together in the intergenerational collaborative project provided a space for the partners to engage in scientific practices that allowed them to be recognized by the larger conservation community. Ernest felt creating and presenting the poster was important as it showed his and Walter's competence in collecting data and using data they collected in the field:

> It's pretty prideful to have that poster at the end so I've got to laminate it for Walter and it's gonna be a nice boost for him. It was a boost for me too. I can show it to my end of the year evaluation… The fact that we presented at [elite university], the fact that we worked with C. goin' out there. The fact that we met a couple of trail people. The fact we presented it at the commission, all of that kinda thing really puts it into data is being collected, data is robust, data can be used. They want a poster now, the

> conservation commission wants to put it up in our offices… They're really impressed with it.

Walter and Ernest were being recognized in the conservation community for their competence and performances in conservation science. Ernest made this connection between scientific practices – collecting and communicating data, competences, and recognition explicit. For Ernest recognition from the conservation community for their project was important, but it was most important for building connections for Walter. This comes back to the recognition that was important for Ernest was from his students and parents. In this case, it was the recognition for his student.

Miguel felt accomplished in helping an urban community understand the importance of green spaces and spending time outside. It seemed that doing the work and getting recognized through local level feedback was the basis of Miguel's self-recognition of his accomplishments:

> But then being able to engage a community like [town] that doesn't really go outside in conversations about why you should go outside, and then hearing that people were actually doing that—that was a huge thing. It's not gonna make any headlines. It's not gonna be, I don't know, on the CNN or BBC, but at least at the local level, that was incredibly important to us, and that was a win for us as well.

Miguel also recognized his improved mentoring skills, "Like I said, roundabout way of saying that because of all of that that's been expected, I feel like now I can contribute better to that one-on-one mentorship relationship." His supervisor also recognized the improvement in his mentoring skills:

> We don't necessarily have a way to measure this, but she did note, "I do think that it's made you a better mentor and at least know how to relate and work with people, or rather with students, a little bit better."

And his supervisor and colleagues noted that he seemed happier working one-on-one with a student on this project:

> They [colleagues] said that they can hear how excited I get about working with the [ICP] program, but especially now that I get to work one-on-one with Julie. My supervisor told me, she was like, "Yeah, I think you're happier when you're doing something like this."

Julie received positive recognition from her friends for her participation in the project:

> I guess the more exciting response would be kids at school like, "That's really cool." and stuff like that. Like, "I didn't even know about that stuff." I showed one kid the map from the QR. He goes, "Wow. I didn't even know you could do that. You can make your own map on Google Maps? I didn't even know."

They were enthusiastic about the idea of creating interactive trail maps. Julie felt somewhat recognized at the conference when they received an award for completing the project, "I guess getting the award for completing it was cool." She didn't feel the people at the conference were very interested in their project, "They didn't seem too excited, or anything. It was just like, 'Oh. Nice. Good job.' That's about it." In the end, she felt she hadn't gotten any negative recognition, just not the recognition she had hoped for. One interaction Julie didn't mention, but which was a form of recognition, was getting to meet and talk with a U.S. senator from her state at the conference. Miguel noted this as a highlight for him, not just because they were recognized by a U.S. senator, but because he felt Julie enjoyed that recognition so much:

> I think that—really, at the end of it, that was my highlight because she enjoyed that. We got a picture with him. It was put on our organizational Facebook page. It was just a really nice high point at the very end of all of it, to show her—it's, like, "Listen. What you did—what we did has a—made a difference or has an impact, and now a senator

knows about that."

Julie did not include the meeting with the senator when talking about feeling recognized at the conference. It may have been that she didn't see him as part of the conservation community. She was a little disappointed in not being positively recognized by the other participants at the conference. Julie was looking to join the larger conservation community and though she didn't receive any negative recognition to deter her in her aspirations, she didn't feel she received anything positive either. Miguel felt the recognition from the community was meaningful for him, but even more meaningful was the recognition for Julie. He viewed the senator as not only part of the conservation community, but important for the larger picture of conservation work in the state. Like Ernest it was important to him that his mentee be recognized for her accomplishments in completing this project.

Keith, Andy, and Ingrid did not feel recognized by meaningful others in relation to their project. The partners related few instances of positive recognition. The one person Keith mentioned who gave him a positive reaction was his former teacher who had participated in the program the year before, "Well, I showed my old teacher the poster that we made. He was like, 'Great work.' I shared the electronic copy with him and so he liked that. He did that program [ICP] last year as an adult mentor." Most of their experiences in the project resulted in no recognition or even negative recognition.

Keith and Andy received negative recognition several times when they met with the watershed association scientist. She made a joke out of Keith wanting to go into STEM. The scientist didn't seem to understand what he meant by the term and rather than ask him, she joked, "But you can't go out and be a STEM artist. I mean you have to have something you do right?" This was negative recognition of Keith's interest. When he replied engineer, she talked over him not hearing his answer. Keith didn't feel positively recognized by family and friends for working on the project. His friends recognized him in a negative way, “They thought I was kind of weird just randomly kayaking on the [river] looking for plastic.” His family seemed neutral about the project, “They didn’t really seem to have any discernable reaction. Like, Great, you’re doing something for the environment. You’re not playing on your phone at home.”

Andy did not recount any recognition from family or friends and the only recognition Ingrid recounted was from her daughter who asked her why she was doing this because it was another responsibility, “Because she knows how hard it is to do a project like this. When you’ve got a lot of other obligations or responsibilities and stuff, and this was just something that was so out of my circle…” None of the partners recounted positive recognition from family and friends.

Keith and Ingrid didn’t feel many people at the conference were interested in their project. Keith and Andy only spoke to a few people and Keith felt awkward because their QR code didn’t work, “Well, it’s kind of awkward cuz the QR code we used apparently had a seven-day trial—and so we were sitting there with a broken QR code and no one actually scanned it at the conference.” Ingrid also did not feel positively recognized by others at the conference for their accomplishment, “No. No, I don’t know that we generated a whole lot of interest with our project.” While the partners didn’t express specific negative recognition for their project at the land trust conference, they did feel a lack of recognition for their accomplishments.

In the first two cases the participants felt recognized in some way by meaningful others. Ernest and Walter felt recognized by the larger conservation community for their performances collecting data on and communicating about the biodiversity of the urban park. Miguel felt recognized by Julie’s community, co-workers, and the larger conservation community at the conference including a senator. Julie felt recognized by the ICP scientists for completing the project. While Julie also received recognition from the senator at the conference, she did not internalize that recognition and did not view it as important to her career trajectory. Receiving recognition from ICP scientists who work in natural resources was more meaningful for Julie than from someone who works in government. Although Julie didn't feel she had received as much recognition at the conference for her project as she would have liked, she didn't receive any negative recognition that might have made her question her career choice. Ernest and Miguel while feeling recognized individually, felt most rewarded by seeing their mentees receive recognition from the larger conservation community.

Keith, Andy, and Ingrid did not feel they had received positive recognition for their project by family, friends, or the larger conservation community at the conference. Keith and Andy received negative recognition from the watershed association scientist for their competence. Keith received negative recognition from friends. Keith and Ingrid felt disinterest from their families and other conference attendees. Ingrid also did not feel competent in mentoring the two teens and negatively recognized herself in that area. The positive recognition in the first two cases supported the development and strengthening of the participants' conservation science identity as seen by their desire to continue in this type of work. The negative recognition or lack of recognition encountered by the participants in the third case did not support identification with conservation science and may have lessened it as they did not express a desire to continue working in conservation science. Ingrid also expressed she didn't wish to continue mentoring teens in conservation science.

### *Social Structures that Promoted Identification with Conservation Science and Technology*

The last set of findings relate to how social structures can affect agency in STEM pursuits (Table 3). I discuss how socio-cultural norms may have affected effective communication and decision making between participants of different ages and cultures and how this might impact successful intergenerational collaborations. Finally, I discuss how connections between the intergenerational collaborative project expectations and the participant's career learning goals promoted a sense of belonging in the conservation community that was important for supportting and strengthening participants' conservation science identities.

*Table 3: Social Structures Affecting Agency in Intergenerational Collaborations*

| Findings | Case 1: Walter and Ernest | Case 2: Julie and Miguel | Case 3: Keith, Andy & Ingrid |
|---|---|---|---|
| *(8) Effective communication was important for establishing and strengthening relationships important for successful collaboration and promotion of STEM identities.* | Partners had a relationship with established means of communicating based on face-to-face meetings | Partners also had substantial face time although they used electronic communication for more than just logistics. | Partners did not have many face-to-face meetings and encountered a mismatch in electronic communications where the teens and adults were comfortable with different platforms. |
| *(9) Adult promotion of student voice and corresponding student agency – active participation in decision making - was important for successful collaboration and strengthening of participants' STEM identities.* | Partners already had established relationship. Walter was able to express his ideas from the start and partners engaged in collaborative decision making throughout . | Partners needed to establish a relationship before Julie felt comfortable talking openly about her ideas and making decisions for the partners. | Ingrid tried to promote teens' voices, but they had not established a relationship where the teens felt safe expressing their opinions if they differed from the adult. |
| *(10) Connections between project expectations and participant career learning goals promoted a sense of belonging in the conservation community important for strengthening participants' conservation science identities* | Ernest already worked in the field of conservation science as a science teacher.<br>Walter saw conservation science as his career focus. | Miguel was pursuing a master's degree in public health and saw connections between the environment and physical and mental health issues<br>Julie saw natural resources as her career focus. | Ingrid was interested in conservation issues, but at a personal level more than as a professional possibility.<br>Keith and Andy were considering engineering, computer science or biology as their future field. |

**Finding 8: Effective Communication was Important for Establishing and Strengthening Relationships Important for Successful Collaboration and Promotion of STEM Identities.** Effective communication between partners promoted successful collaboration by: (1) facilitating logistical decisions necessary for the completion of their projects, and (2) providing opportunities for the partners to learn from and with each other. Logistical decisions such as arranging meetings, delegating tasks, and sharing information were often communicated through digital means such as phone calls, email, or texts. This involved determining the method of communication that was comfortable for each partner regardless of age and deciding on the method they would use. It also involved timely responses to messages. For two of the cases, communication was not an issue. Both the teens and the adult initiated communications and typically received timely responses. In the third case, lack of effective communication was seen as a challenge to the successful completion of their project and inhibited sharing of information.

Ernest and Warren had a history of working together before their participation in ICP. Ernest used a flip phone and could not text. The partners communicated by phone or email to set up meetings but did most of their communicating in person. The collaborative project provided a space for Walter and his former teacher to work together on a common project which was different from the other programs in which Ernest and Walter had been involved. Ernest felt that working together on a collaborative long-term community-based project made their relationship even stronger. The ICP project provided an opportunity for the two of them to work more collaboratively, on a more equal footing than previous experiences. At times this seemed to blur the lines of traditional teacher-student positioning. Ernest and Walter worked on their presentation poster at Walter's apartment. It was the first time Ernest had been to Walter's home. Working together on this project, allowed Ernest to have a more in depth understanding of Walter's life. One reason he wanted to mentor Walter was he saw not only the promise in

Walter's passion for learning but also the difficulties Walter and his family faced financially:

> Money is a big issue for Walter's family. It's a huge issue, but it's unsaid. There would be pride hurt and that kinda thing if it was even out there, but he really can barely afford much of anything. I think about that kid that went to Costa Rica that—Walter sees that, and Walter never complains, never whines, never—but he just dreams of doin' it himself. [Shows emotion] Sorry.

Ernest saw his responsibilities as the adult as taking care of organizational issues although he recognized that at times, Walter took the initiative:

> I'm the adult, he's got a lot of peripheral things happening that are kid, kid and teenage related. Although, he was pretty good. He was the one most recently that got in touch with me. Mr. S. are we gonna be doin' this and I didn't get back to him. It was like a week and a half ago he emailed me. I haven't gotten back to him thinking I'm gonna see him here. Yeah, he's done a little bit of initiation. I've done a little bit more initiation.

Ernest and Walter shared the responsibility for communicating logistical information and were responsive to each other throughout the project. Ernest discussed how participating in programs together was not a new thing for Walter and him, but that working together on a collaborative long-term community-based project was more serious and made their relationship even stronger:

> It was, this was not like a new thing. Walter and I have been doin' stuff together anyway. This was cementing it and it did a good job. Cuz it was just, instead of me and him goin' out and just messing around, this was like doin' something serious.

The partners spent most of their time communicating face to face, relying on digital communications only for setting up meeting times. Communicating face to face created an environment more conducive to sharing information–both about the project and their lives–deepening their relationship and facilitating decision making that impacted the project:

> I've seen Walter in a different light, you know, instead of just showing up at a meeting. We go to meetings, we go to walks, we do Envirothon, so here in the house for the first time, actually hanging out. That stuff is a different look.

Face-to-face communication also promoted recognition between the partners of each other's competences and performances as they worked together to complete the different phases of the project further supporting each's identification with conservation science.

Originally Julie and Miguel saw Miguel's role as the coordinator who would be in charge of communicating logistical information to the team. Miguel also saw his role as trying to meet the needs of two teens and help them refine their ideas for the project. This involved helping them pick an idea they were interested in and determining the correct steps to achieve their goals. Miguel didn't view the teens as needing help with the science or technology part of the project – more the logistical details and transportation. This customary role of a mentor as coordinator aligned with Julie's view of Miguel's role, "I mean, I guess the adult would—they're more for scheduling and stuff. Like I've said, 'You know, let's have a meeting,' and then nothing really happens, but if he said anything, I would definitely be there." Miguel, however, recognized that Julie was often the one initiating communication to keep the partners on track, "I will say that the students definitely kept me on track, especially Julie. *[Chuckles]* 'Cause she would text me, like, I haven't heard from you about this." Julie and Miguel ended up sharing the responsibility of contacting each other about the project.

As Miguel and Julie spent time together working on the project they came to know each other better and learn from each other. Miguel learned about the area–both local ecology and history. Julie learned about the relationship between the environment and public health. Julie and Miguel both saw Miguel's role change from facilitator to full partner in the project, "It was definitely partnership, number one, where we were doing equal amounts of work."[Miguel]

Julie mentioned how it was different working with Miguel than with a teacher because they worked together to complete the project. Julie and Miguel spent a considerable amount of time face-to-face working on the project. She appreciated working with an adult because she felt adults were more reliable than teens in completing the work:

> Yeah. I shouldn't have said teacher 'cause it wasn't like I was sitting there listening to a talk. We were working on stuff together, like, putting a poster together. I guess it was more like I liked working with someone more mature instead of someone my age that'd probably never get done project. You can use that as a fact.

While Julie and Miguel used both digital and in-person communication, they shared the responsibility for initiating discussions and responding in a timely manner. Neither felt that communication was an issue in successfully completing their collaborative project. Spending time together working on the project face-to-face also enabled them to discover more about each other, recognize their different resources and shared interests, and deepened their relationship.

Keith, Andy, and Ingrid felt communication was an issue in their partnership. Part of this may have been related to having three partners rather than two. Coordinating three schedules to find common time was mentioned as an issue by the adult and teens. Keith felt a major difficulty in the project was coordinating everyone's different schedules since he and Andy were involved in afterschool activities and Ingrid worked:

> Just getting all our schedules to align, honestly. 'Cause I have a—I'm very active outside of school as well, and I have a bunch of extra-curriculars, and then, I do all honors and AP classes, so I've got a struggle with school as well, so… Yeah. And then, Andy's the same. And then, Ingrid has a job, so.

All three partners only got together twice, the first time to try to find access sites to the river and the second was to meet with the watershed association scientist. Keith and Ingrid got together to canoe and collect samples. Keith and Andy got together at Andy's house one time to process the samples and they also met with the ICP coordinator to create the presentation poster. All other communication was done digitally. Keith mentioned that having a timetable would have helped with communication and scheduling times to get together:

> Maybe just designing a timetable or something, saying when you're available, when you aren't, and all the communication with your teammates, as far as how to, when you're available and when you can meet and all. And also, making meetings in advance, because last minute things don't always work out.

Keith recognized that communication was one of the biggest challenges for this team. Keith and Andy weren't accustomed to using email or phone calls and Ingrid was not accustomed to texting and didn't use snapchat:

> I feel like the only problem there was communication just cuz we didn't really use any of the same mediums. Andy and I would text or Snapchat each other and then we'd email Ingrid. It was kind of hard to organize everything.

Their communication mismatch had a generational component to it. Keith and Andy communicated mostly with snapchat and secondarily by texting, "We just texted each other about it. And, yeah… We just ask each other the problem and then we just offer responses until whoever asked it, or the rest of us decided on an adequate solution." Much of this communication was between the two teens. Ingrid found communication with the teens challenging at times since she preferred talking on the phone:

> We did not talk a lot on the phone, or as much as I tried to encourage them to have a little conference call, tell me a time when I can call, when you guys are both available. I would just not get any responses. I would not get a reply. Then it mostly became—the most common time we were talking was the monthly conference call with [ICP coordinator].

When she emailed the teens, she often did not get a reply. Ingrid became increasingly frustrated with the lack of communication from the two teens:

> It was a little frustrating at times. I guess there were a number of times when I didn't think we were going to make it. It was like, "No, this is not going to happen." [ICP coordinator] did a really great job at keeping us going, keeping us motivated and I really appreciated that.

When the teens were unresponsive to her attempts to communicate, Ingrid was unsure of her role in pressing the teens to move forward with the project:

> It was a little difficult because the boys were very busy with school and so they were not always responsive. That was a little—for a while I really wasn't sure if they wanted to continue with the project. I felt like it was a little bit too demanding for me to keep after them all the time.

Eventually she consulted the ICP coordinator about the situation and was encouraged to try one more time. Ingrid discovered that including the teen's parents in emails resulted in more replies from the teens, "Oh, here's something: always include the parents in e-mails… You get responses much better that way." She also met with the parents and found that establishing a relationship with them was key to working through the communication issues to complete the project:

> Yeah. At first it was a little awkward. I wasn't sure how to connect with the parents, exactly what I was supposed to say to them, cause I knew I was gonna have to work with them, but they're 15 years old. I can't just drive to their house and pick them up and take them somewhere. I have to—okay, what do I say to the parents? I did get in touch with them and met with both the moms, and they were both very sweet and really supportive, and I talked to them about I'm gonna pick 'em up and do stuff with 'em. I

hope you guys are okay with that.

The lack of face time and difficulties in electronic communication between Ingrid and Keith and Andy, hindered the development of a meaningful relationship between the adult and the two teens. The three partners spent very little time together working on the project and didn't learn about each other or from each other in order to establish a feeling of true collaboration.

Effective communication is essential to the development of any relationship. In these partnerships, efficiently communicating logistical details and sharing information was important for collaborative decision making and a sense of ownership by all members of the partnership. Spending time together face-to-face facilitated sharing of information and recognition of each other's resources. Walter and Ernest already had a relationship. They had an established means of communicating based on face-to-face meetings. Phone calls and emails were only used to set up times to get together. They spent the majority of their time on the project working together in person. This means of communication further enabled their recognition of each other's competences and performances promoting their conservation science–and for Walter, technology–identities. Julie and Miguel also had substantial face time although they used electronic communication for more than just logistics. Their time spent together allowed them to get to know each other beyond their work on the project. This was important for Julie to feel comfortable expressing her ideas. Due to the effectiveness of their communication, Miguel and Julie were also able to recognize each other's competences and performances in the project supporting the development of their identification with conservation science–and for Miguel–technology. Keith, Andy, and Ingrid did not have many face-to-face meetings and encountered a mismatch in electronic communications where the teens and adults were comfortable with different platforms. The lack of face-to-face time hindered this team in developing meaningful relationships between the adult and the teens and negatively impacted their combined sense of ownership of the project. The adult and teens did not share information about themselves, or recognize each other's competences and performances missing an opportunity to further develop their identification with conservation science and technology.

**Finding 9: Adult Promotion of Student Voice and Corresponding Student Agency – Active Participation in Decision making - was Important for Successful Collaboration and Strengthening of Participants' STEM Identities.** In all three cases, the adults tried to promote the teens' voices by asking for their opinions when making decisions. Simply asking the teens for their input, however, was insufficient to create a space where the teens felt they could contribute to the decision-making process. Before the teens could feel comfortable expressing their ideas, they needed a relationship with the adult where they felt safe sharing and pushing back on the adults' ideas. This involved spending time together in or out of the project and getting to know each other.

Ernest and Walter already had an established mentor/mentee relationship where Walter was able to express his ideas from the start and the partners engaged in collaborative decision making throughout the project. Sometimes Ernest took the lead and other times Walter. Walter described the process of making decisions together during the project:

> Let's see. For decisions, we mostly agreed on what the project was gonna be about, and then we just revised it as we went along to something that would fit better for what we were doing. For the project, it was basically decided since we have our two different specialty areas, that we would just split off to do those and then work together on the mammals, reptiles, and amphibians since we both know a good amount about those species. Then, for the rest of it, it was just on the spot. For the technology aspect, we split it a little bit, and then we just kept on going, putting more and more information that we had until we decided that we were ready to use it for a rough draft.

When Walter described the process of making decisions in the project he felt the initial decision was easy to make because they decided to use their two different specialty areas. They worked on their individual parts and then came back together to share and revise to make the parts fit. When creating the poster, Walter expressed his voice by asking Ernest questions to move the pair along, “all right. Do you want to do the basic or the expanded template?” Walter began to take charge by delegating tasks, “So, should we just start from the top? … So, what do you want our title to be actually? … I think I’ll do the draft here and then once you.” Walter also took the lead in creating the wording of different parts of the poster:

> So how about this, 1. We want people to become more interested in nature, umm) and in the park [typing] interested in the park, 2. We want to um, we want to change the reputation of the park like with its vandalism and illegal dumping.

Walter was able to push back on Ernest’s idea of including sensitive information about the park they were studying. Ernest wanted to include how they were trying to change the reputation of the park from a gay man’s hangout where people had been arrested for illicit activity. Walter felt it was outside their project’s focus. In the end, the partners decided to leave out the information as Walter had suggested.

Ernest’s and Walter’s strong relationship allowed Walter to voice his opinions in the decision making process throughout the project. Ernest listened to Walter’s ideas and the partners often chose Walter’s ideas over Ernest’s. This is another instance of recognizing Walter for his ideas and promoting his identity as someone who understands and can contribute to conservation science.

Julie and Miguel needed to establish a relationship before Julie felt comfortable talking openly about her ideas and making decisions for the partners. She did however, express her idea about wanting to create educational pamphlets of green spaces around [town] in the beginning of the project. At that time, Miguel and Julie were working with another teen, Stephen, who wanted to do a qualitative study about food deserts. They were thinking of sending out electronic surveys. Julie and Miguel decided the pamphlets would be the project's focus:

> This seems a little more straightforward. I was speaking to Julie in the other room while you were talking to Stephen, and since she works there [town's recreation department], she's like yeah, they would be more open to if we created a pamphlet of some sort so that they can hand it out instead of using it electronically.

The partners decided on the brochure about green spaces due to Julie's connection with the recreation department and her view that the department would like to have the pamphlets. While Julie's voice was promoted in the decision about the focus of the project, Stephen's was not and may be part of the reason he eventually lost interest.

When Julie and Miguel worked together to create their presentation poster, Miguel checked with Julie before writing anything into the presentation. Miguel described how they made decisions in the project by generally sitting down and talking about it in person, or on the phone:

> Every single step of the way, there's something that came up, as I'm sure lots of other projects did, all of the projects did. Yeah, but it was generally just a sitting down, talking about it, or calling each other on the phone, or just texting or emailing. I think once we found the core group that we wanted to work with between myself and Julie, it generally went a lot smoother and faster.

Julie and Miguel also used texting and email to communicate. Similar to Keith, Andy, and Ingrid, Miguel felt that having three people made communication and decision making more difficult than between just two people. Miguel believed the process of making decisions should be the same for any group of people. The age of the participants should not be a consideration.

Talking through the problem should be the main method:

> I hope that if—with any group that we work on, whether it's teenagers, adults, or whatever, that the process is the same and that, hey, we think there's a problem. Let's just sit down and talk about it. Yeah.

Julie mentioned she was used to being around older adults and appreciated working with them because she could be more direct than with teens. With another teen she would have been more self-conscious and concerned about hurting the other teen's feeling when expressing her ideas:

> Probably be like too shy to even talk to them [other teens] or something. I don't think we'd get as much done, probably. If I was working with another kid from school or something I'd be like, I'd have to listen to what they have to say and be nice to their feelings and stuff. With an adult it's like, 'No. I want to do this.' I can speak more maturely.

Her comments about working with other teens may have been influenced by the initial dynamics of two teens working with Miguel. While the voices of both teens may be promoted in decision making, it may not be possible to combine both ideas into one project. One person's idea may end up chosen over another's. In this case, Julie's idea was chosen over Stephen's. Miguel felt it took time for Julie to become comfortable enough with him to push back on his ideas. When the two worked together on the poster presentation, Julie was able to voice dissent with the wording of the poster and promote her own ideas:

> It's nice to see her grow as a student. She didn't say a word to me the first time we met, by the way. She's very quiet. [Chuckles] Seeing her grow as a person who felt comfortable telling me something as simple as, "I think the wording should be different here," she wouldn't have told me that back in the summer. Yeah, I think that was—

because I worked so closely with her.

Miguel promoted Julie's voice throughout the project, though not perhaps, Stephen's. Working together on the project helped Julie and Miguel establish a positive relationship that promoted Julie's voice and allowed her to feel she could express her opinions and become a full partner in decision making.

Keith and Andy did not spend as much time with Ingrid on their project as the teens in the other partnerships and did not establish a relationship where they felt comfortable expressing their ideas. Their hesitancy to initiate conversations with adults may have decreased their role in decision making and their engagement in performances. During the meeting with the watershed association scientist, neither teen asked questions nor offered opinions. Keith hardly spoke during the meeting. Both teens appeared to be listening intently to the conversation, always facing the speaker and nodding their heads in agreement to points the adults were making. When either teen answered a direct question, they answered with few words, often a single yes or no. When the Andy and Keith met with the ICP coordinator to create the presentation poster, they did not initiate discussion. They rarely made eye contact with the coordinator. The majority of the time they looked directly at their computer screens. Again, they answered the coordinator's direct questions, but only rarely asked their own questions and only for clarification. In both meetings, Andy's and Keith's hesitancy to speak diminished their voices in making decisions about the project.

Keith stated that canoeing was out of his comfort zone yet referenced the trip as an enjoyable way he interacted with Ingrid, "I mean, once we could actually get things organized, it was fun working together like the canoeing." Throughout the canoe trip and sample collection, Ingrid initiated conversation with Keith. Keith answered her questions without elaboration. Keith was hesitant during the sample collection and waited for instructions. He did not use either phone he brought while they were at each site to take pictures or create waypoints. He deferred those responsibilities to Ingrid and let her do all of the technology performances. Keith's hesitancy to take initiative diminished his ability to engage in performances such as sample collection and digital mapping.

Andy's parents did not allow him to go on the canoe trip which was the major data collection trip. He hadn't shared with Ingrid his parents' concerns about the canoe trip until after the arrangements were made. The partners could have figured out an alternate way of collecting data if Andy had been more forthright about his inability to swim.

After processing the samples, Andy and Keith did not show their results to anyone besides their parents. They did not keep the microplastic samples or show them to Ingrid:

> I wish they had just saved it and showed it to me… That was like, "You don't have it anymore? What'd you do with it?"... 'Cause that would've been a significant quantity for the little pieces of samples that we were taking for there actually if that had been a microplastic. I would say, "Did somebody, maybe an animal got a beanie baby or something."

Ingrid stated she felt really good about the project and their results but had never seen the sample of microplastics. As related earlier, the teens relied on their own interpretation of the sediments and their parents – none of whom have expertise in soil sediments. This hesitancy to show the samples to anyone who might be able to identify microplastics calls into questions what the teens actually found.

While Ingrid and the ICP coordinator tried to promote the teens' voices in decision making by continually asking for their input, the teens did not feel comfortable expressing their opinions and ideas. The lack of time spent together on the project created a barrier to establishing a positive working relationship where the teens might have felt more comfortable sharing their ideas and pushing back on the ideas of the adults.

Asking teens for their ideas was insufficient to promote their voices in decision making. The ability to promote the teens' voices depended on effective communication and successful relationship building. This was evident in the first two cases where the partners spent substantial amounts of time together in the project. The teens knew or came to know their adult partner well enough to feel safe expressing their ideas and pushing back on the adults' ideas. In the third case, the adult tried to promote the teens' voices, but the partners had not established a relationship where the teens felt safe expressing their opinions if they differed from the adult.

**Finding 10: Connections Between Project Expectations and Participant Career Learning Goals Promoted a Sense of Belonging in the Conservation Community Important for Strengthening Participants' Conservation Science Identities.** The three adults and four teens in these case studies decided to participate in the ICP program because they were interested in environmental issues, but only some of them saw learning about conservation science and geospatial technologies as furthering their professional learning goals. One of the adults already worked in the field of conservation science–Ernest as a science teacher. Miguel was pursuing a master's degree in public health and saw connections between the environment and physical and mental health issues. Ingrid was interested in conservation issues, but at a personal level more than as a professional possibility. Two of the four teens (Walter and Julie) saw conservation science or natural resources as their career focus, while the other two (Keith and Andy) were looking at engineering, computer science or biology as their future field. The adults and teens who saw the program as furthering their career learning goals were more invested in their projects, felt more recognition from the larger conservation community, made connections with researchers and other members of the conservation community, and felt successful in their collaboration.

Walter and Ernest entered the program as a pair to further their understanding of how geospatial technologies could be used in conservation work. Ernest had been studying and working in conservation science most of his life. Walter was already on track to major in a conservation science field. The opportunity to collaborate together in the ICP project aligned with their career learning interests. Ernest viewed Track Kit as a skill he and Walter could continue to use on future projects - Walter in his Tiger Beetle project:

> No, there is overlap because what we're doing with the mapping and trail, and all that kind of stuff…We want to employ the same techniques when Walter starts doing the tiger beetle research.

and Ernest in his intentions to provide professional development for other teachers. Ernest also viewed this project as a way to further Walter's future career by connecting Walter with the conservation community and researchers at different universities:

> We do have a relationship with F. D. now. He's one of the key [town] people. We did go present to the conservation committee commission… We liked presenting down at [university]. This is a lot of stuff that's very good to get Walter acclimated to thinking higher level plane. He's been at [elite university] for the entomological society, he's been at [another prestigious university], so I think this is gonna help him think a little bit bigger… Being at [university] and meeting all these different people and you felt more connected. It's almost like you're part of this collegial group. Socialization especially for a high school kid, getting that goin' at this stage it just broadens their horizons and raises their expectations for themselves I think.

Ernest recognized the importance of going beyond receiving recognition for competence and performances to developing connections with the larger scientific community. Meeting scientists and developing relationships with them would help Walter feel he belonged in this community.

Beyond recognition, Ernest felt that establishing connections for Walter to develop a sense of belonging in the academic world of conservation science was critical for Walter's future in science.

Julie saw the ICP program as aligning with her desire to major in natural resources in college. The collaborative project helped her further her connections in her community as she created informational brochures to be distributed by her town's recreation department. Providing her town with a resource based on her interest in conservation helped to establish her as someone who contributes to her community and to the conservation science field:

> Yeah, 'cause I didn't wanna speak to the parks and recs until they already had our pamphlet to bring to them, 'cause I had nothing to show them. They'd be like, "What do you want me to do?"

Learning about geospatial technologies and incorporating them into the project was not as important for Julie as working towards her goal of a career in natural resources. Miguel was not working directly in conservation or planning on pursuing a career in conservation science, but he saw a connection to his chosen field of public health. Miguel saw the project aligning with his desire to help communities understand the importance of the environment for their physical and mental health and his interest in mentoring youth. The awareness project also aligned with his goal of making scientific information accessible to all people:

> I think that was a big, big reason why we ended up doing the project in this way. One of the things that Jen and I talked about but didn't come up today was the idea of science being accessible to everyone. Whether it was creating a vocabulary list or an appendix or something like that at the back of our pamphlet.

Miguel discussed creating a glossary at the back of the pamphlet or translating it into some of the many languages spoken in the community. Miguel saw the importance of making connections to the community for himself and Julie. Like Ernest, he was excited at the opportunities presenting at the land trust conference offered for Julie to meet people in the conservation community and begin to see herself as part of it.

Keith, Andy, and Ingrid were newcomers to conservation science. Ingrid did not work in the field or have any experience working on conservation projects. Keith saw his trajectory leading to a career in engineering or computer science. Andy was thinking about majoring in computer science or biology in college. His experiences in biology so far had been laboratory-based rather than in the field. Andy and Keith were concerned about environmental issues and thought it would be interesting to check out a program where they would work together and engage in field work. Ingrid cared about environmental issues and about the youth in her community who didn't get research opportunities in school. She wanted to engage them in their community through a community conservation project.

Keith did not see his future career being in conservation science but thought he might be able to incorporate conservation issues into his career interest of robotics, "Well, I mean, not as a specific career or interest but I could maybe draw parallels between some of my other interests and this like maybe designing robots that would clean up. Yeah." At the end of the project, Ingrid was still thinking about how to disseminate the information to a larger audience – perhaps through the canoe company. She was also thinking about what the next steps would be in the research. Ingrid demonstrated her desire to keep learning about microplastics and her interest in the research. She was still interested in conservation work but indicated she did not want to continue in this work mentoring students in conservation projects.

Ernest and Walter, and Julie and Miguel felt successful in their project and recognized by each other and the larger community. All saw the collaborative project aligning with their career learning goals. Each expressed the desire to continue in conservation work and the adults wished to continue mentoring students. For these four participants, their experiences in the intergenerational collaborative project strengthened their identification with conservation science. For Ingrid, Keith, and Andy they felt successful in completing the project but did not feel recognized by each other or the larger community. They did not see the collaborative project aligning with their career learning goals. Keith did not want to continue in this type of work but could see it being an application for his career focus in robotics. Ingrid expressed a desire to continue getting involved in conservation work, but not in mentoring future students in this program. For Keith, the intergenerational collaborative project did not strengthen his identification with conservation science and may have lessened it. For Ingrid, it did not strengthen her identification in conservation science but did not seem to diminish it, although it may have lessened her identification as a mentor.

As shown initially in figure 1, successful collaborations leading to strengthened identification with conservation science all recognized and valued the partners' historical STEM identities and personal resources and incorporated them into the collaborative project. The collaboration provided opportunities for the partners to recognize and be recognized for their competences and performances in conservation science leading to further connections with the conservation community. Alignment of the participants' personal career learning goals, project expectations and larger conservation community goals enabled recognition from the larger conservation community promoting a sense of connection to the conservation community. The partners recognized themselves as understanding, using, and contributing to conservation science, the definition of having a STEM identity.

# Chapter 5: Discussion and Conclusion

The findings from this study coalesced into three themes as shown earlier in Table 1: (1) findings related to the historical STEM identities of the participants, (2) findings related to constructs of STEM identification in the intergenerational partnerships, and (3) findings related to social structures impacting adult and teen agency. While I discuss each theme separately, there is considerable crossover of the themes in the promotion of STEM identification for the participants. I first discuss the findings about the participants' historical identification with STEM fields.

## Findings Related to Historical STEM Identities

The first three findings pertain to the historical STEM identity of the participants. Two of the findings were specific to the adults in each partnership. It was found that: (1) the adults who recognized their own competence in conservation science also felt more competent mentoring their partner(s), and (2) those adults who demonstrated an understanding of how global environmental issues are connected to local issues were better able to facilitate intergenerational collaborations across different communities. The third finding, relevant to all participants, was that prior connections to nature and enjoyment of outdoor activities promoted positive engagement in conservation fieldwork performances. These findings support earlier studies that have demonstrated correlations between competence, performances and recognition in the development of a STEM identity (Carlone & Johnson, 2007).

The adults in the three cases recognized themselves with regards to three kinds of competence in the project: (1) knowledge and understanding of conservation science, (2) ability to use technology, and (3) ability to mentor. While researchers in the initial workshops shared their vision of intergenerational collaborative learning rather than a mentor/mentee model, the three adults continued to refer to themselves as mentors for their teens. The adults all felt competent in STEM fields, but only the two who felt competent in conservation science also felt competent mentoring teens in the program. A similar correlation to competence in the use of technology was not found. Feeling competent in conservation science and mentoring led to feelings of overall success in the partnerships.

Ernest, Miguel and Ingrid, like many adult STEM learners, were motivated to participate in the project to continue learning about a specific domain of science related to their interests and problems of everyday life (NRC, 2009; Sachatello-Sawyer, 2006). But interest alone was not sufficient to feel competent enough in the science to mentor a teen. Dovidio, Piliavin, Schroeder, & Penner (2006) define mentoring as "an action that has the consequence of providing some benefit to or improving the well-being of another person" (p. 22). It follows that to feel competent in mentoring, one must feel they confer a benefit on the mentee. Self-recognition by the adult of competence in conservation science undergirded their self-recognition in competence in mentoring a teen. Erikson (1968) postulated that humans are driven to attain competence when they engage in fields of interest, but, competence only becomes part of identity when it is recognized. That recognition must be internalized by the individual as self-recognition and then may manifest in social performances (Hazari, et al., 2015) such as mentoring. This aligns with Gee (2000) who considers recognition at the heart of identities, and Carlone and Johnson (2007) who found competences and performances must be recognized by meaningful others to be internalized as self-recognition.

My findings support the importance of competence in STEM identification but also suggest that competence is specific to the STEM field in which the pursuit in embedded. The pursuits of consequence in this research included mentoring teens while engaging in a conservation project. The two adults who recognized themselves as competent in conservation science also felt competent to mentor their teens in the project. The one adult who recognized herself as competent in physical science, math, and engineering, but not conservation science did not feel competent to mentor her teens in their conservation project. My findings also support Klieme, et al.,'s (2008) assertion that expertise is developed over time through experiences and training. The three adults entered the program at different stages in their development of competence in conservation science, technology, and mentoring. Ernest had developed the most competence in conservation science and mentoring. He recognized his own expertise in conservation science but continued participating in activities that would further his learning in this field for his own enjoyment and to help him share this knowledge with his students. While Ernest had been mentoring students in conservation science for many years, Miguel and Ingrid were just beginning. Miguel was able to recognize that he had sufficient competence in conservation science to mentor Julie although he did not consider himself an expert. Ingrid did not feel she had enough competence to be an effective mentor. Ingrid was measuring her own competence against a priori definitions of good science (Carlone, 2012; Kelly, et al., 1998) and found herself lacking. Without the competence she felt she needed she didn't feel empowered to guide her teens in their collaborative project. Adult self-recognition of competence in conservation science promoted adult agency to engage in the practices needed to support their teen in the collaborative project and supported their identity as someone who can participate and contribute to a STEM field.

The second finding is an offshoot of the first finding. One of the competences in conservation science that was found to be important in facilitating a project among participants who live in different towns was the ability to see how global environmental issues are connected to local community concerns. Understanding the link between local and global allowed the adult to facilitate a project in a different community from their own while seeing relevance for all communities. My findings support Archer, et al.'s (2010) conception of a STEM identity as the embodied and performed constructions realized through the tension between an individual's agency and the constraints in their specific, structural locations. Ingrid viewed the physical location of the project as a constraint due to her localized view of conservation issues. She felt she didn't know anything about the teens' communities and their communities' needs and lost her sense of agency in facilitating the project. She did not have a level of competence—understanding of the connections between global and local—to support her agency and identification with conservation science. Miguel and Ernest did not view the location of the project as a constraint due to their global view of conservation issues and felt enabled to facilitate a project in any community. Their level of competence supported their agency and identification with conservation science.

My first two findings support earlier research demonstrating the importance of competence in developing a STEM identity, while also adding nuance to the type of competence that supports an adult in an intergenerational collaborative project. The focus of intergenerational collaborative STEM learning is different from other STEM mentoring programs in that the adult is not expected to be an expert in the field but is interested in learning alongside their teen counterpart. My findings point to how the adult benefited from having sufficient competence in the specific STEM field. This supported them in understanding the connections between big ideas or core concepts rather than discrete facts or specialized knowledge in ways that made them feel competent mentoring a teen in that specific STEM field. These findings are important to help informal STEM programs understand how to best support adults entering into intergenerational collaborative learning projects who are not considered experts in the field.

My third finding concerning the historical STEM identity of the participants was that prior connections to nature and enjoyment of outdoor activities promoted positive engagement in conservation fieldwork performances. Many of the activities the participants engaged in prior to participation in the collaborative project were precursors to the performances needed to carry out field work. One of the components of a STEM identity is being able to successfully engage in scientific performances to accomplish consequential pursuits (Carlone & Johnson, 2007; Hazari,et al., 2015). Performances, defined as, “a patterned set of actions performed by members of a group based on common purposes and expectations, with shared ways of talking and using tools” (Carlone, 2012, p. 16) for the collaborative intergenerational conservation projects entailed spending significant amounts of time outdoors observing, identifying, and collecting data, as well as trail mapping. While these performances are situated in the social interactions and sociohistorical traditions in each case (Carlone, 2012), they are also located physically in an outdoor environment. Those participants who had previously spent significant amounts of time outdoors—hiking, identifying and collecting plants and insects, going to the beach, and different parks—had developed attitudes towards nature based on concrete experiences rather than abstract ideas. It was easy and enjoyable for them to engage in the required performances of fieldwork. The two teenagers who had not spent time outdoors had an abstract idea of engaging in fieldwork that was different from what they experienced in the project. They did not enjoy the performances necessary in field work and did not wish to continue engaging in them. As a result, they did not spend significant amounts of time outdoors in nature during their project. My findings support the importance of an emerging construct, ways of seeing and being which incorporates Carlson’s (2010) notion of aesthetic appreciation - the attitudes that develop from immersion, participation, and intellectual struggle within natural environments, and Jaber & Hammer’s (2016) conceptualization of epistemic affect and motivation (i.e., the feelings and drives connected to developing knowledge of a subject area). Participants who spent significant amounts of time engaging in and reflecting on nature-based activities developed an appreciation for natural environments. Immersing themselves in nature affected the way they viewed the natural world and influenced their actions concerning natural environments. The participants who recognized themselves as successful in the collaborative project and wished to continue with experiences in this field – those who's conservation science identities were strengthened – came into the project with historical STEM identities tied to previous enjoyable experiences in nature. This is not to say that only participants who have had previous nature experiences will find fieldwork enjoyable, but having these concrete experiences prepared them for the reality of performances necessary for fieldwork in their collaborative projects. This adds to previous findings that participation in informal learning programs is mostly from those with already well-developed interests (Lipstein & Renninger, 2006; Renninger & Hidi, 2002; Renninger, et al., 2004). Prior related experiences develop interests from abstract ideas to more concrete understandings. This finding is especially important for promoting conservation science identities in populations without previous opportunities to engage in activities in natural environments such as urban youth and adults. To begin engaging in conservation fieldwork, populations with little prior experiences in natural environments may benefit by engaging in abbreviated introductory experiences prior to taking on a longer-term conservation project or need supports as they experience the reality of being immersed in the messiness of the natural world.

**Findings Related to STEM Identity Constructs in the Intergenerational Partnerships**

The next four findings relate to the constructs of competence, performances and recognition in the intergenerational collaborative projects and how they intersect to promote the development and maintenance of a STEM identity. Participation in the intergenerational collaborative project promoted identification with conservation science by (1) providing a platform for the demonstration of competence in conservation science, (2) providing opportunities to engage in performances necessary to complete a long-term project, (3) providing opportunities to recognize and utilize the resources each participant brought to the project, and (4) providing opportunities for positive recognition from meaningful others.

My findings support previous findings that opportunities to participate and demonstrate competence is important for developing and maintaining identification with a STEM field (Carlone, 2012; Carlone, et al., 2011; Gresalfi, et al., 2009). In each partnership, there were opportunities to participate in performances to demonstrate competence. The definition of competence in a particular setting is determined through the interaction between participation in performances and recognition of those performances by the individual and group as demonstrating competence (Carlone, 2012; Gresalfi et al., 2009; Lottero-Perdue & Brickhouse, 2002). Group-level meanings of competence depend upon how the group recognizes those performances as demonstrating competence (Carlone, 2012; Carlone, et al., 2011; Gresalfi, et al., 2009). My findings indicate that competence, performances, and recognition are not only inextricably linked, but reciprocally reinforcing in promoting identification in a STEM field. The participants entered the program with different levels of competence in conservation science. This affected the amount of participation in performances during the project. Engagement in performances demonstrated competence allowing for recognition by self, partner, and meaningful others promoting further engagement in performances to develop more competence with more opportunities for recognition. The participants who entered with higher levels of competence in conservation science (i.e., Ernest, Walter, Miguel and Julie), spent more time working on their project engaging in performances, felt more recognized for their competence, and desired to continue participating in conservation science endeavors. Those who entered with less competence in conservation science (i.e., Ingrid, Keith and Andy) spent less time on the project, engaged less in performances, felt less recognized and did not express a desire to continue participating in conservation science endeavors.

Two of my findings concern important forms of recognition in the partnerships for successful and meaningful intergenerational collaborations which could support STEM identity authoring: (1) recognizing and utilizing the resources each participant brought to the project, and (2) positive recognition from meaningful others.

The first finding supports social practice theory's focus on interpersonal interactions during engagement in practice within local and socio-historical structures. People develop their identities through activities (e.g., performances of practices) but due to their unique differences they each may encounter diverse struggles (Carlone, 2012). Each participant brought unique prior experiences, background knowledge, beliefs, values, and interests they could contribute to their partnerships if not constrained by larger structures including race, gender, culture, economics, history (Greeno, 2006; Gresalfi, et al., 2009, Varelas et al., 2011) and age. For intergenerational collaborations the difference in age and associated norms of interaction represent another social structure affecting the partners.

In the first two partnerships many of the participants' resources (e.g., knowledge of insects and plants, history of local community, knowledge of public health) were recognized, valued, and incorporated into the project. Recognizing a person's various resources recognizes their identities. This aligns with Cote and Levine (2002) who claim that validation of a person's role and integration in a community can be a source of ego strength. Those participants who had their resources incorporated into the collaboration had their identities validated as worthwhile and meaningful. For Walter and Ernest this recognition of prior resources initially was focused on competence and performances in conservation science. During their interactions in the project, other resources such as Walter's facility with writing and problem solving with computer technology were recognized. For Julie and Miguel, the recognition of resources focused not just on conservation science knowledge, but also on other areas of interest that could add to their project. Julie's knowledge of local history and Miguel's knowledge of public health were incorporated into their project. Tempest (2003) considers recognition of each partner's resources as key to intergenerational learning and collaboration. Collaboration between partners at different life stages enhances the learning of both. Bjursell (2015) emphasizes how the goal of intergenerational learning should be the co-creation of knowledge, values, and innovation. This is reflected in youth/adult partnerships (Y/AP) where each age group is seen as a resource for the other (Camino, 2000). This type of mutual recognition of resources was demonstrated in the first two cases.

Keith, Andy, and Ingrid did not recognize the resources they each brought to the project (e.g., competence in engineering, physical science, robotics, and computer science) as valuable in this context and did not incorporate them, missing a valuable opportunity to validate their STEM identities. This partnership seemed to view learning in a more traditional manner where younger persons learn from elders (Cozzi, 1998; Bailey, 2009). Ingrid expressed multiple times how she felt her lack of competence affected their project. She felt she needed to know more about the topic than the teens. This attitude can hinder the recognition of each other's resources and opportunities for mutual teaching and learning found to be effective in Y/AP (Camino, 2000). This aligns with Bailey (2009) that found adults may feel their power threatened if they admit to ignorance about a topic. Younger teammates may also feel uncertain and have difficulties communicating. Andy and Keith demonstrated a reluctance to share any resources they might have had that could contribute to their project. The NRC (2009) recognizes the need to allow learners to use their unique background and experiences in order to promote broad and inclusive participation in informal learning programs. My findings support this necessity. In the context of intergenerational STEM learning this finding is important to understand the necessity

of participants getting to know each other and their resources with the intent of incorporating their
resources into their collaborative projects.

All three partnerships saw an important adult resource as their ability to organize and facilitate projects. Adults and teens initially viewed this as the adults' primary responsibility in the partnership. During the course of participation in the project, two of the partnerships (Walter and Ernest, and Julie and Miguel) changed their perceptions of the adult role from organizer to full partner engaged in all aspects of the project. A key component of this change in view was recognizing the resources of the adult as more than facilitating logistics of the project.

Recognition of a person's identification with a STEM field by meaningful others may influence the development of the participants' STEM identities (Barab and Hay, 2001; Markowitz, 2004; Robbins & Schoenfisch, 2005) and depends on engagement in STEM practices across time and space (Barton, et al., 2008; Carlone, 2004; Kang, et al., 2019; Polman & Miller, 2010). Due to the differences in their ages, the adults in the collaborative partnerships had engaged in practices over a longer period of time than the teens and had developed more stable STEM identities. This can even be seen within the adults as they ranged in age from late twenties to mid-sixties.

Carlone and Johnson (2007) found recognition by meaningful others to be important for the type of STEM identity (e.g., research, altruistic or disrupted) that is promoted (Table 4). My findings support and extend the characterization of these different types of STEM identity by types of recognition. Carlone and Johnson (2007) found altruistic STEM identities in successful women of color in health fields. My findings also found altruistic STEM identities in teachers/mentors in STEM. Ernest and Miguel exhibited altruistic STEM identities where meaningful recognition came from their students/mentees or others with similar altruistic goals.

Miguel also valued recognition from the target community where he hoped to improve their quality of life. Ernest's form of altruistic STEM identity could be classified as a STEM

*Table 4. STEM Identities by Type of Recognition (Carlone & Johnson, 2007)*

| Type of STEM Identity | Type of Meaningful Recognition | STEM Career Field |
|---|---|---|
| Research | STEM Research Scientists, STEM professors/teachers | Research |
| Altruistic | Others with similar altruistic aims<br>Own Community<br>Target Community or individuals being served | Applied - Health field |
| Disrupted | Negative recognition or<br>Recognition for other identities not salient to competence in STEM | Research or Applied/Health |

teacher /mentor identity while Miguel exhibited a mix of Carlone and Johnson's (2007) altruistic health science identity and a STEM teacher/mentor identity. During the project, Walter exhibited a research STEM identity and appreciated the recognition from his mentor and other scientists he worked with on the project. Walter also related that he enjoyed teaching others about insects and beetles, perhaps showing the beginnings of a STEM teacher identity. Both Miguel and Walter exhibited and were recognized as having different types of STEM identities often at the same time aligning with Gee (2000) who emphasized the dependence of identities on recognition by others and oneself as "acting and interacting as a certain kind of person or even as several different kinds at once in a given time and place" (p.99).

Julie was beginning her pathway into conservation science and did not yet exhibit a STEM identity that could be labeled research or altruistic. The recognition she received came mostly from her partner, teacher and peers. She did not feel recognized by her family or by the larger conservation science community at the land trust conference, but also did not feel she had received negative recognition during the project. While Miguel felt that recognition from the senator would be meaningful for Julie, Julie did not mention the encounter. Hazari, et al. (2015) found for external recognition to support the development of a STEM identity, it must be internalized by the individual as self-recognition. It is unclear if Julie internalized the recognition she received from the senator. She did, however, positively recognize her accomplishment in completing the project with her partner.

Ingrid, and Keith did not feel recognized for their accomplishments in the project, and Keith and Andy had received negative recognition for their competence in conservation science by the watershed association scientist during the project. All three exhibited an identification with STEM fields other than conservation science. Negative recognition has been found to inhibit integration of identities (Barton, et al., 2008; Carlone, 2004; Kang, et al., 2019; Polman & Miller, 2010). My findings support this in that Keith was unable to integrate conservation science into his STEM identity. Ingrid encountered negative recognition in her past for being a woman in a STEM field—engineering—but persevered. Her historical STEM identity could be classified as disrupted according to the type of recognition she received during her education. During her participation in the project she did not feel she had received much recognition and while not wanting to continue her participation in the program the next year, she was keeping the door open for possible future engagement. Ingrid's disrupted STEM identity in engineering may make her more resilient if she decides conservation issues are important enough to her to continue in this work in the future.

**Findings Related to Social Structures and Intergenerational Learning**

The last set of findings pertain to the role of social structures in collaborative intergenerational partnerships. I found that successful collaborations that could lead to promotion of STEM identification were dependent on: (1) effective communication for establishing and strengthening relationships between the intergenerational partners, (2) adult promotion of student voice and corresponding student agency – active participation in decision making, and (3) alignment of program expectations and the participants' lifelong learning goals.

Much of the literature on intergenerational STEM learning involves family members such as parent/child or grandparent/child (Istead & Shapiro, 2014). There has been much less research into nonfamilial intergenerational interactions though studies have consistently shown that intergenerational communication can be problematic (Williams & Nussbaum, 2001). My findings are important in they add to the literature on STEM identification by showing how interactions in nonrelated intergenerational partnerships support or constrain STEM identification and learning.

Effective communication is accepted as crucial to any collaborative enterprise, yet interpersonal communication has been found to be unclear, inexact, and inherently flawed (Coupland, N., Giles, and Wiemann, 1991). Communication between individuals of different generations has great potential for misunderstandings and the risk of miscommunication increases as the age difference increases (Williams & Nussbaum, 2001). Generational cohorts have been viewed as different developmental cultures and intergenerational communication is seen to have features of intercultural communication (Coupland, N. & Nussbaum, 1993; Giles & Coupland, 1991; Williams & Nussbaum, 2001). My findings show that effective communication was important in intergenerational collaborations and point out a generational component that is unique to our rapidly changing digital media environment. Today we have more ways to communicate than ever before, yet a mismatch in preferred communication modes underscored one partnership's biggest challenge. The partners' preferred mode of communication mattered for establishing a relationship where the participants became comfortable enough with each other to share their ideas and opinions, "intergenerational communication both takes place within relationships and simultaneously defines relationships" (Williams & Nussbaum, 2001 p. xii). The partnerships that established an agreed upon mode of logistical communication that supported more in person interactions, felt they communicated effectively and developed more meaningful relationships, ultimately feeling more successful in their collaborative projects.

In the case of Walter and Ernest, the partners agreed to use Ernest's preferred modes of communication—in person—with phone calls used mostly to set up meeting times. Walter and Ernest had the largest age difference between them, yet established a relationship through their mutual interest in conservation science. They experienced what Williams (1992) termed mutuality where the partners found common interests that diminished the sense of age gap. Mutuality has been found to be important to young people's satisfaction in intergenerational communication. The younger partner found the elder to have positive characteristics such as being "positive, animated, zestful, admired youth, and was nonjudgmental" (Williams and Nussbaum, 2001 p. 84). Two other factors identified by Williams (1992) and evidenced in Ernest and Walter's case, were elder individuation and young individuation. These factors are defined as the person feeling recognized as an individual and not as an age-stereotype with resulting free expression of ideas.

Julie and Miguel had the smallest difference in ages but would still be classified as different generations according to their different developmental life experiences. Julie and Miguel also communicated mostly in person although they used other media more than Ernest and Walter. Both Julie and Miguel were comfortable with each mode of communication. Mutuality, elder individuation, and young individuation were also evident although Miguel is only classified as elder in regard to his relationship with Julie. Julie and Miguel also support William and Giles (1996) findings that intergenerational conversations may be anxietyprovoking at first, but over time the younger partner begins to feel more relaxed and at ease. For these two partnerships mutuality was a supportive feature of their intergenerational conversations. Mutuality differs from socioemotional support because it refers to the achievement of true common ground, equality, and mutual supportiveness in their interactions (William & Nussbaum, 2001).

Ingrid, Keith, and Andy did not spend much time together in person. Their partnership had the second greatest difference in ages and a resultant mismatch in preferred modes of communication. Ingrid expressed similar communication preferences as Ernest (i.e., in person followed by phone calls and email), but unlike Walter, Keith and Andy continued to use mostly digital communications and they preferred to use an app unfamiliar to Ingrid. Walter engaged in the concept of convergence which comes out of communication accommodation theory (Giles, 1973; Giles, Taylor, & Bourhis, 1973.; Soliz & Giles, 2014). In convergence, a person makes their communication patterns more like their conversation partner. Walter was willing to use the modes of communication most comfortable for Ernest. Keith and Andy, however, engaged in divergence where their modes of communication emphasized the differences between themselves and their partner, Ingrid (Giles, et al., 1973; Williams & Nussbaum, 2001). This often resulted in a lack of communication between the three partners and hindered the development of their relationship.

The partnerships that engaged in the practices together and communicated predominantly in person co-constructed meaning about their experience, their positions, and views about their competence thus supporting each other in their learning and identification with conservation science. My findings add to the literature by showing the importance of matching communication modalities between generations and not only speech patterns. Varelas et al. (2011) describes identity as lived experience based on collective history and produced through interactions where a person is heard and seen in particular ways and hears and sees others in particular ways. Development of mutuality, elder and young individuation were important factors in developing a relationship where each partner felt supported and heard thus promoting the identification of the adult and teen in conservation science.

The second social structures-related finding supports a main principle of the youth/adult partnerships (Y/AP) model for intergenerational learning—adult promotion of youth voice (Camino, 2000). My findings, however, show that not only must adults promote student voice by actively working to engage youth in decision making, there must be a corresponding willingness on the youth's part to enter into decision-making conversations. Youth must have agency to participate in decision making when the door is opened by adults. Agency in STEM refers to the capacity to act independently and make decisions and contributions in STEM pursuits (NRC, 2009). Carlone (2012) discusses how an individual's identity work can be seen in their bids for recognition by showing what is important to them. This idea emphasizes individual agency. One way to demonstrate agency is by making bids for recognition through sharing one's resources and opinions. To make a bid for recognition, one must value one's own resources enough to overcome social structures that inhibit agency. A prominent, though not necessarily always foregrounded, social structure in these collaborations is the difference in ages of the participants - the norms of interaction between teens and nonfamilial adults. Intersecting with the identities of the participants as teen or adult are their identities related to gender, race, and ethnicity.

In all three partnerships the adults were seen trying to promote student voice and engage their partners in the decision-making aspects of the project. Two of the teens—Julie and Walter—demonstrated agency through their participation in decision making and were able to make successful bids for recognition in their partnerships. This included responding to adult questions that asked for their input and initiating questioning of the adults to further their collaborative project. Keith and Andy, however, showed little agency in decision making and made few bids for recognition. Over the course of the project they rarely initiated conversations, typically only responding to direct inquiries from adults or asking questions for clarification of what the adult wanted them to do. Individuals will make bids for recognition when they see their behavior in line with the privileged in the local culture (Carlone, 2012; Gee, 2000). Teens may view the privileged in an adult-run program as the adults. At the beginning of the project, the two teens were interested in doing a water quality project, but Ingrid did not feel they could collect worthwhile data in such a short timespan due to seasonal fluctuations. The teens did not pursue that project but switched to a project on microplastics thinking they could collect valid data in a shorter period of time. They may not have argued for their original idea of water quality testing as they didn't see the adult as wanting to pursue that project.

Other social structures that may affect student agency in decision making are race and gender. There was no evidence of this in the partnerships of Ernest (White male) and Walter (African American male) or Julie (White female) and Miguel (Latinx male). Julie was quiet and soft spoken from the beginning of their partnership, but she was not hesitant to propose her idea for a green space awareness project and continue to argue for it when initially deciding on their project. Cultural influences, however, may have affected Keith's (South Asian male) and Andy's (South Asian male) agency working with Ingrid (White female). Values that have been attributed to South Asian parenting are obedience to parental rules, respect, and acceptance of the decisions of elders (Hines, Garcia-Preto, McGoldrick, Almeida, Weltman, 1992; Maiter & George, 2003). Keith 's and Andy's reluctance to offer their ideas and opinions may be culturally-based in their respect for elders. They may not have felt it was appropriate to be involved in decision making. This relates to social practice theory in pointing out the educational issue of structure vs agency.

Developing an identity is affected by macrolevel structures pushing back on an individual's choices and behavior (Bronfenbrenner, 1976; Varelas, et al., 2015).

The last finding related to the structure agency dialectic also connects the participants' historical STEM identity and participation in the intergenerational collaborative project. It was found that participants who made connections between their work in the collaborative project and their lifelong career learning goals felt more connected with the conservation community and demonstrated a desire to continue in this work. Their conservation science identity was promoted and strengthened through their connection to an affinity group (Gee, 2000) or community of people connected through conservation practices and similar goals. To be part of that community necessitates a struggle between who the community wants a person to be and who that individual desires to be (Carlone & Johnson, 2007; Holland, et al., 1998). This can be seen in the match between their lifelong career learning goals and the expectations and goals of the community.

Walter and Ernest made connections to the conservation community through their collaborative project. They met with scientists in the field and during the land trust conference. One goal of Ernest's was to help Walter make connections in the scientific community and the collaborative project facilitated those connections. Walter's goal was to pursue a degree and then career in entomology or conservation science. The project supported those goals giving him opportunities to demonstrate his competence and performances to the larger conservation science community. This aligns with Carlone and Johnson's (2007) emphasis on the structural component of identity where a person must be recognized for their competence and performances and accepted in the field by meaningful others. Further, validation and a sense of integration into a community strengthens a person's ego identity (Cote and Levine, 2002).

Julie's goal, similar to Walter's, was to pursue a major and then career in conservation science. The collaborative project was her first experience working in the field and she saw the value in it for her future aspirations. While Miguel's career goals were in public health, he was able to make connections between the collaborative project on green space awareness and his chosen field. He recognized the value of green spaces for improving mental health in a community. Miguel saw the conference as a place where Julie received recognition for their project. Although Julie didn't receive the recognition she wanted, she didn't feel she had received negative recognition that would cause her to not continue on her path. Her goals still aligned with the goals of the conservation community and the project still had the potential to further her goals in the future.

Keith and Andy did not have personal goals to pursue a degree or career in conservation science. They were interested in conservation issues and in the application of technology to solve problems, but their career goals were in other STEM fields. Most participants in informal science learning environments choose to participate due to interests and needs (Dierking et al., 2003), but Keith and Andy participated due to their parents' encouragement and the thought that they would meet other teens in the program. In the end, they did not see their collaborative project supporting their goals and they did not feel a connection to the conservation community. Ingrid did not have professional goals related to conservation science, but she did have personal goals related to conservation science in her community. Her goals were specific to her community and engaging students in her community in research experiences. Working on a project which she didn't relate to her community and with teens from a different community did not align with her personal goals.

Overall, my findings show the importance of considering each partner's historical STEM identity for successful participation in intergenerational collaborative STEM partnerships. This includes not only recognizing and valuing their interests and competence in the STEM fields involved, but also their experiences, personal resources, and lifelong learning goals. Social structures such as cultural norms for intergenerational communication and decision making need to be recognized as affecting intergenerational interactions and role expectations for teens and adults. My findings show promise for intergenerational collaborative STEM partnerships as an an effective way for teens and adults to learn from and support each other in the development of their identification with a STEM field.

**Limitations**

There were several limitations to this study: (a) The amount of time participants spent working on the projects, (b) Loss of participants in one partnership during the yearlong project, (c) Lack of participation by all participants in one partnership during observations and interviews, and (d) Weaknesses inevitable in case study evidence (Yin, 2018).

The amount of time participants devoted to working on their conservation projects was variable across partnerships and relatively short when considering changes in STEM identities. Although the workshops were held in the summer, many teams did not begin working together on data collection until late autumn and the conferences were held in March. This resulted in a shorter length of time the teams worked together.

In the second case three teens and one adult attended the initial workship. One teen had to drop out after the intial workshop when her family moved. The second teen left in February after their data gathering concluded. An initial observation and interview were conducted with this teen, but I was unable to conduct a final interview after he left the project. His perspective on the collaboration would have added to findings for that team. Because he left the program data analysis focused on the adult and the one teen who was in the program the entire time.

The three participants in the third case did not participate in all observations and interviews. The first observation was when the participants met with the watershed association scientist. Due to the lateness of the hour when that observation finished, I was unable to interview the three participants. The second observation was the data collection trip by canoe. Andy did not accompany his teammates due to his inability to swim. I was unable to interview him after that observation. Instead, I combined the protocols for the first and second interviews and conducted his interview after his second observation with the ICP scientist.

I was unable to conduct the final interview immediately after the conference as the participants were unable to stay for the amount of time required. Final interviews took place over a 6-week timespan after the conference. Andy did not respond to multiple requests for a final interview after the conference.

Finally there are inherent weaknesses in case study research. Participants may act differently because they know they are being observed (and video recorded). Bias may be introduced when the researcher participates in field activities. There is always the concern of response bias in interviews when participants may not want to appear negative when speaking about challenges in the project or about working with their partner. Participants may also be inclined to say what they think the researcher wants to hear. This may be especially true when the focus of the research is on partnerships. To address this issue, I triangulated data from observations and interviews as well as secondary sources such as posters, emails and forum posts.

**Conclusion**

This dissertation aimed to address the lack of positive STEM experiences for many people that support identification with STEM fields by investigating the experiences of teen and adult partners in a novel informal STEM program designed to promote intergenerational collaboration and learning. My research sought to illuminate connections between the participants' historical STEM identities, their engagement and interactions in intergenerational conservation projects, and the impact of relevant social structures on the participants' agency in STEM pursuits. STEM identity authoring was examined in each case study through three constructs: (1) competence in knowledge and understanding of conservation science and technology, (2) performances of practices in science and technology, and (3) recognition of competence and performances by self and meaningful others. Overall, this study sought to understand factors in intergenerational STEM partnerships that might promote STEM identity authoring and lifelong learning.

This conclusion will provide insights derived from the most salient findings for supporting STEM identity authoring in adults and teens in intergenerational collaborative STEM partnerships. These findings reveal: (1) important aspects of adult and teen historical STEM identity that need to be considered by informal STEM programmers to provide support for intergenerational collaborations, (2) facets of intergenerational collaboration that promote STEM identity authoring and (3) social structures related to intergenerational communication and decision making that may support or constrain intergenerational collaboration, learning and STEM identity authoring. While the findings may seem specific to conservation science, they may have broad application across STEM fields when applied to intergenerational learning.

***Historical STEM Identity and Intergenerational STEM Collaborations***

Two of the three aspects of the participants' historical STEM identity that were associated with successful intergenerational conservation collaborations were: (1) adult competence in conservation science, and (2) adult understanding of connections between global and local environmental issues. Adults who recognized themselves with higher levels of competence in conservation science felt more competent as mentors and had more successful collaborations. Adults who demonstrated understanding of the global nature of conservation issues where they could make connections to issues across communities also had more successful intergenerational collaborations. No correlation was found between teens' level of competence in conservation science or the participants' competence in technology. The third finding related to the historical STEM identities of the participants is pertinent to STEM fields where outdoor field work is required. Participants who already had many outdoor experiences in natural environments were better prepared for the reality of fieldwork, enjoyed working outdoors, and engaged in more outdoor performances throughout the project.

The expectation of the Intergenerational Conservation Partnership program was for teens and adults to work collaboratively on a project where they could both learn about conservation science and geospatial technology. The three adults, however, all felt that one of their roles was to mentor their teens in conservation science. While programs may emphasize collaboration, normative roles for adults and teens create an expectation that the adult will be the mentor and the teen the mentee. This has important implications for collaborative intergenerational STEM learning programs. Informal STEM learning programmers need to be aware of the importance of revealing, valuing, and incorporating important aspects of the participants' historical STEM identity to support successful collaborative STEM learning experiences. Revealing the historical STEM identities of the adults will assist programmers in supporting adults without strong competence levels in the relevant STEM fields to overcome feelings of inadequacy they may experience in the partnership and to recognize other resources they bring to the collaboration. Programmers should also be aware that adult partners may need to be supported in understanding the overarching core ideas of a STEM field before digging into the specifics of a project. Finally, it is important for informal STEM programmers to take note of the physical nature of previous STEM experiences participants have had. If participants have not spent significant amounts of time in nature, they may need explicit explanations of what working in the field can be like to align their expectations with the reality of fieldwork. They may also need additional supports from program personnel while in the field to feel comfortable and safe while outdoors in natural environments.

***Intergenerational STEM Collaborations and STEM Identity Authoring***

Facets of intergenerational collaboration found to support STEM identity authoring included: (1) demonstration of competence in conservation science, (2) engagement in performances to complete a long-term project, (3) recognition and utilization of partners' personal resources, and (4) positive recognition by meaningful others. My findings support similar findings of the importance of positive recognition of competence and performances in STEM fields (Barab and Hay, 2001; Carlone & Johnson, 2007; Markowitz, 2004; Robbins & Schoenfisch, 2005), but broaden recognition to include personal resources. In addition to recognizing personal resources, it was important to show the value of those resources by actively incorporating them in the scientific pursuit.

These findings suggest that Informal STEM programmers should intentionally provide opportunities for partners to get to know each other's resources– not just previous experiences in the particular STEM field or interest areas. Positively recognizing and incorporating personal resources positively recognizes the whole person and their many identities. This increases opportunities for each partner to be recognized by meaningful others. During the partners' initial project design phase, specific strategies should be incorporated to help partners get to know each other and what each brings to the partnership beyond competence in specific STEM fields. Explicit prompting by programmers can help participants to actively look for each other's resources that could be used in the project.

***Communication and Decision Making in Intergenerational STEM Collaborations.***

Two areas where social structures were found to potentially affect participant agency in the collaborative project were communication and decision making between the partners. The intergenerational partners who used mutually agreed upon communication modalities were found to have more effective communication between the partners promoting the development of supportive relationships. Further, it was found that partners who spent more time communicating in person also spent more time together engaging in performances increasing their opportunities to recognize each other. Adult promotion of youth voice through verbal requests for youth ideas was found to be insufficient for collaborative decision making. Evidence from the three case studies suggests youth agency in decision making may be impacted by the intersection of age and socio-cultural norms.

These findings suggest teens and adults would benefit from strategies to promote agency in communication and decision making. Explicit conversations about social and cultural norms between generations would raise participants' awareness of how historical socio-cultural ways of interacting between generations could constrain their collaborations. Included in these conversations should be discussions of digital communication modes each partner uses and recognition of the importance of face-to-face time to engage in performances together. For effective communication, accommodating the older generation in preferred communication mode may increase adult agency in the project. ISL programmers also need to be aware of constraints on student agency stemming from socio-cultural norms associated with intergenerational interactions. Programmer-facilitated discussions around adult and teen role expectations and decision making strategies may help promote student agency in decision making.

The findings from this research support intergenerational collaborative STEM learning as a promising new approach for promoting lifelong STEM identity authoring. To realize the potential of intergenerational collaborative partnerships more research is needed about: (1) ways to elicit and promote incorporation of partners' historical STEM identities and personal resources in collaborative projects, (2) strategies to promote conservation science identity authoring in older teens and adults who have had few or no previous experiences in natural environments, and (3) strategies to support effective communication and collaborative decision making between nonfamilial intergenerational STEM partners.

Additional research areas I would like to pursue related to STEM identity authoring include examining: (1) how informal science experiences that involve authentic community projects pairing teachers and teens affect the teacher's STEM identity and agency, and attitudes towards formal science instruction, (2) how early outdoor STEM experiences affect adult identification with conservation science, (3) how different STEM identity constructs intersect in different types of STEM identities (e.g., altruistic, research) and identification in different STEM fields (e.g., technology identity, engineering identity).

My research aimed to add to the body of knowledge on how individuals develop and maintain an identification with a STEM field by investigating a novel informal intergenerational STEM learning program. Through an in-depth examination of three case studies, I found three areas where informal STEM programmers can support STEM identity authoring in intergenerational collaborative partnerships: (1) by promoting sharing of partners' historical STEM identity and personal resources and considering how they can be incorporated into collaborative projects (2) by fostering development of supportive relationships between the partners based on recognition of each other's unique background, set of knowledge and skills, and shared experiences in the project, and (3) by supporting effective communication and decision making between the partners through scaffolding and explicit discussions of intergenerational socio-cultural norms.

## Appendix A: Conservation Training Partnership Observation Protocol

*This protocol was developed to assist in identifying different constructs in the development of a STEM identity. The protocol is broken down into sections on competence, performance of epistemic, communicative and investigative practices, self-recognition, recognition by others, ways of seeing and being and influence of social structures.*

**Directions:** Tally instances and note time on video of the following competences and performances as you observe them and provide some notes/examples on the right to add context such as when and where they occurred. . There is also space to add to this list if necessary. Once the observation is over, please take a moment to write a thick description of what you observed and attach it to this checklist.

**Competences:** *Knowledge and Understanding of Conservation and Natural Resource Concepts and Knowledge and Understanding of Geospatial Technologies*

1. **What are the celebrated and marginalized competencies and ways of demonstrating competency?**
2. **What are the times and places for demonstrating competency?**
3. **Who is responsible for demonstrating competency?**
4. **What artifacts are produced that demonstrate competency?**
5. **What tools are used to demonstrate competency?**
6. **What are reasons for demonstrating competency?**
7. **What feelings/affect are displayed when demonstrating competency?**

| | **Times Observed** | **Notes/Examples** |
|---|---|---|
| Knowledge of conservation science and natural | | |

| | | |
|---|---|---|
| resources | | |
| Knowledge of Geospatial technologies | | |
| **Performances of Practices (***Social performances of relevant science practices—e.g., ways of talking and using tools)*<br>1. **What are celebrated and marginalized ways of performing this practice?**<br>2. **What are times and spaces for performing this practice?**<br>3. **Who is responsible for performing this practice?**<br>4. **What tools are used for performing this practice?**<br>5. **What are reasons for performing this practice?**<br>6. **What kinds of artifacts are produced?**<br>7. **What feelings/affect are displayed?** | | |
| **Epistemic Practices -** The ways in which learners observe, infer, justify, explain, evaluate, and legitimate scientific knowledge | **Times Observed** | **Notes/Examples** |
| **Scientific Observation:** | | |
| **Inferring:** | | |
| **Justifying:** | | |
| **Developing scientific explanations:** | | |
| **Evaluating Scientific Explanations:** | | |
| **Legitimating Scientific Explanations:** | | |
| **Communicative Practices -** The ways in which learners communicate with one another and their instructor as they engage in scientific practices. | **Times Observed** | **Notes/Examples** |

| | | |
|---|---|---|
| These can be verbal, graphical, etc. | | |
| **Between Teen Learners and Adult learner** | | |
| **Between Teen Learners and Scientist** | | |
| **Between Teen Learners** | | |
| **Between Adult Learners and Scientist** | | |
| **Investigative Practices -** The ways in which learners investigate using prior knowledges to learn more and explore their local environments. | **Times Observed** | **Notes/Examples** |
| | | |
| **Use of geospatial technologies -** The ways in which learners use geospatial tools to inform their projects | **Times Observed** | **Notes/Examples** |
| **Recognition (***Ways in which the participant was recognized by self or others)*<br>1. **What are the celebrated and marginalized ways learners recognize themselves?**<br>2. **What are the celebrated and marginalized ways learners make bids for recognition?**<br>3. **What are the celebrated and marginalized ways learners recognize each other?**<br>4. **What are the times and places where learners recognize themselves or others?**<br>5. **What are the reasons learners recognize themselves or others?**<br>6. **What are the feelings/affect displayed during self-recognition or recognition by others** | | |
| **Self -Recognition** | **Times Observed** | **Notes/Examples** |
| **Positive recognition of self as science person** | | |
| **Negative recognition of self** | | |

| | | |
|---|---|---|
| **Positive recognition by meaningful "scientific" others** | | |
| **Negative recognition by meaningful "scientific" others** | | |
| **Positive recognition by "nonscientific "others"** | | |
| **Negative recognition by "nonscientific "others"** | | |
| **Ways of Seeing and Being** (Attitudes such as empathy, wonder, appreciation, respect toward natural world, conservation science and technology and actions such as ways of speaking, protecting, educating) | **Times Observed** | **Notes/Examples** |
| **Related to natural world (wildlife, plants, ecosystems)** | | |
| **Related to conservation science (managing, protecting natural resources** | | |
| **Related to technology (use of GIS, GPS)** | | |
| **Social Structures (Group Norms)**<br>1. **What are the celebrated and marginalized ways learners establish, and maintain group norms?**<br>2. **Who is responsible for establishing and maintaining group norms?**<br>3. **What are the times and places where learners establish and maintain group norms?**<br>4. **What are the reasons learners establish and maintain group norms?**<br>5. **What are the feelings/affect displayed when group norms are established and** | | |

| **maintained/not maintained** | | |
|---|---|---|
| **Social Structures (Group Norms)** | **Times Observed** | **Notes/Examples** |
| Active listening and consideration of team member's ideas and different ways of making sense of the world | | |
| Active support of team members in using their ideas, capabilities (e.g., technological skills), different ways of making sense of the world, and different experiences as resources for resolving community-based concerns or problem | | |
| Recognition of team member's developing ideas, capabilities, and problem-solving strategies as needing to be made public and collaboratively refined to support individual and group learning | | |
| Recognition of contribution of team member's community histories, values, and knowledge-building practices to scientific understanding and problem solving. | | |

Finally, after completing the observation, please take time to write a 1-2 page narrative description of what you observed with as much detail as you think is important. Particularly, in addition to reflecting in narrative form what you captured above, the following are some additional things you might consider including:

- A description of the community within which this meeting took place including the following:
    - The roles or titles of those involved (community partners/ teen) [No identifiers/names]
    - The motivation or pursuits of the group (i.e., what are they trying to accomplish in the meeting?)

**<u>Notes:</u>**

## Appendix B: CTP Initial Interview

Interviews will take before or early in learners' participation in their community land use project to reveal the participants' historical STEM identity.

1. Could you please describe how you came to participate in the CTP (Conservation Training Partnership) project: (Possible Follow-up: How did you find out about it? Who influenced you to take part in it?)
2. How do you think of yourself in regards to science? (Possible Follow-up: Are you a science kind of person? (What does that mean to you?) What do you like/dislike about science? Have you always liked/disliked science? What kinds of science?)
3. Has anyone had an influence on how you feel about science? If so, who? (Possible Follow-up: Has/Did anyone encourage(d) you to pursue a career in science?)
4. How do you think of yourself in regards to technology? Are you a techie? (What does that mean to you?)
5. Has anyone had an influence on how you feel about technology? If so, who? (Possible Follow-up: Has/Did anyone encourage(d) you to pursue a career in technology?)
6. What kinds of positive/negative experiences have you had in science-related pursuits? (Classes, clubs, hobbies, work-related)
7. What kinds of positive/negative experiences have you had in technology-related pursuits? (Classes, clubs, hobbies, work-related)
8. How did you come to be matched with your partner? (Possible Follow-up: Did you already know each other? How did you meet?)
9. What are your expectations for working with a teen/adult in this project? (Possible Follow-up: How do you see your relationship in this project?)
10. What do you think your role will be in this project? Your partner's role? (Examples:

content expert, technology expert, organizational, motivational)

11. Are you involved in any groups that work with conservation issues? (Examples: school clubs, land trusts, conservation commissions, non-profits)
12. How did you and your partner decide on your CTP project? (Examples: your idea, your partner's ideas, both had the idea, combined ideas)
13. How have you and your partner made organizational decisions for your project?
14. What would you say are the most important science ideas to know for informing your group's project? Why are these science ideas important?
15. What, if anything additional would you like to share about your experience so far in the CTP project?

## Appendix C: CTP in Field Interview

Interviews (1-3) will take place immediately after learners are observed taking part in community land use project, so that observational data can be triangulated with participants lived experiences.

Part 1: Participants' Open-ended Description of Experience (field work activities, responsibilities, success and challenges)

1. Please describe your experience today in the CTP (Conservation Training Partnership) project: (Possible Follow-up: What kinds of things was the group working on? What were your responsibilities?  What were the responsibilities of others that may have been different from yours? What did you learn from today's experience? What success and challenges did you experience? What could have made it better?)

Part 2: Performances (social performances of relevant scientific practices—e.g., ways of talking and using tools)

2. What kinds of things, if any, do you think you did today or in the project on other occasions that helped to solve a problem or decide between multiple options for solving a problem? (e.g., Participate in brainstorming solutions? Explain important science or technology concepts? Communicate ideas clearly to the group? Clarify others people's ideas for the group? Organize information to make it more understandable? Keep discussions on track and respectful? Use strategies such as use of evidence, observations, or prior scientific knowledge? List/debate pros and cons?)
3. What are some tools or resources that you used today or at other times in the project that were helpful in moving the group toward achieving your group's project goals? (e.g., ArcGis, online mapping tools, maps, etc.)
4. I want to share one or two things that that I observed today and I'd like you to tell me

why you thought to do this and how you thought it was helpful. (focused on epistemic, communicative or investigative performances)

Part 3: Competences (knowledge and understanding of science ideas and concepts)

**5.** Are there any science ideas or concepts that you can identify that were used by the group today or at other times in the project to help shape decisions and make progress toward achieving your CTP project goals?

**6.** What would you say are the most important science ideas to know for informing your group's project? Why are these science ideas important?

**7.** I want to share one or two science ideas that I observed today and I'd like you to tell me why you thought this science idea was helpful in your group's work?

Part 4: Recognition (recognized by oneself and getting recognized by others)

**8.** What do you feel were your most important contributions to the group's work? In what ways have others recognized or acknowledged your contributions to the group's work? (e.g., praise, given air time, ideas requested/considered/adopted, ideas given credit when shared, assistance in tasks requested, opinions requested, included in decision making)

**9.** Are there ways that you sometimes don't feel recognized for your contributions to the group's work? If so, can you describe these instances? (e.g., no praise, talked over in the group, ideas not listened/considered/adopted, negative responses to ideas, credit for work given to another, assistance/opinions not requested, not included in decision making)

**10.** I want to share one or two interactions that I observed today and I'd like you to tell me what you thought about this interaction and how it made you feel. (focused on recognition)

Part 5: Social Structures (ways cultural meanings are produced in everyday practice in ways that reflect and/or counter larger social structures)

11. In your project, what are some ways that people in the team contribute that are most helpful? Are there some things that they do that are more helpful than others? Are there some ways that people contribute that are not helpful? (e.g., ask for everyone's ideas and actively listen, take charge and assign tasks, allow each member to contribute, participate in brainstorming solutions, explain important science or technology concepts, communicate ideas clearly to the group, clarify others people's ideas for the group, act as the peacemaker negotiating for both sides of an issue, organize information to make it more understandable, keep discussions on track and respectful)
12. Are there other people outside the team that have been important to this project? How have they been important? (e.g., parents, land trust members, NRCA staff)
13. I want to share one or two interactions that I observed today and I'd like you to tell me what you thought about this interaction and how it made you feel. (focused on norms and social positioning)

Part 6: Ways of Seeing and Being (Attitudes such as empathy, wonder, appreciation, respect toward natural world, conservation science and technology and actions such as ways of speaking, protecting, educating)

14. What, if any, changes has this project had on how you view the natural world or technology or how they can work together? (e.g., change in respect, empathy, appreciation, wonder)
15. What, if anything additional would you like to share about your experience so far in the CTP project?

## Appendix D: CTP Final (Reflection) Interview

The final interview will take place at the poster session or after the final field observation to reflect on the participants' meaning making in the CTP project and explore their possible emerging STEM identity

Part 1: Intergenerational Partnership Experience (expectations, successes, challenges)

1. Please describe your overall experience in CTP (Conservation Training Partnership)?
2. How do you feel the intergenerational partnership worked? (Possible Follow-up: Was it what you thought it would be? How do you think this experience would be different if you worked with another teen/adult?)
3. What success and challenges have you experienced working with your partner in this project?
4. What could have made the experience better? (Possible Follow-up: What do wish you would have known before you started? What would you tell to a person thinking of doing this project next year? What have you learned about working with teens/adults?)

Part 2: Performances (social performances of relevant scientific practices—e.g., ways of talking and using tools)

3. What kinds of decisions had to be made in this project and how were they made? (Possible Follow-up: What was your role in the decision- making process? What was the role of your team members? Did making decisions develop into a kind of routine or was it different depending on the type of decision? What do you think is an effective way of making decisions when working with a teen/adult? Do you think decision making be different if you worked with another adult/teen?)
4. What tools and resources have been most valuable in this project to move towards achieving your team's goals? (e.g., ArcGis, online mapping tools, maps, etc.)

Part 3: Competences (knowledge and understanding of science ideas and concepts)

5. Were there any new science ideas or concepts that you learned during the course of this project because they were needed to either help shape decisions and/or make progress toward achieving your team's goals? (Possible Follow-up: How would you compare your knowledge of conservation science from before and after participating in this project? How about geospatial technologies? What kinds of things have you learned?)
6. What would you say are the most important science ideas incorporated in your team's final project? (Possible Follow-up: Do you feel that these ideas science ideas important? Why? Do you feel that learning about geospatial technologies is important? Why?)

Part 4: Recognition (recognized by oneself and getting recognized by others)

7. What do you feel were your most important contributions to the project? In what ways have others recognized or acknowledged your contributions to the team's work? (Possible Follow-up: What kinds of reactions about this project have you gotten from your friends/family (or other school faculty)? How have you talked to them about it?)
8. Are there ways that you sometimes don't feel recognized for your contributions to the group's work? If so, can you describe these instances? (e.g., no praise, talked over in the group, ideas not listened/considered/adopted, negative responses to ideas, credit for work given to another, assistance/opinions not requested, not included in decision making) Follow-up (How did you feel about presenting the poster at the conference? How do you feel your project was viewed by others?)

Part 5: Social Structures (ways cultural meanings are produced in everyday practice in ways that reflect and/or counter larger social structures)

9. In your project, what are some ways that people in the team contribute that are most helpful? Are there some things that they do that are more helpful than others?

**10.** Were there other factors or people outside the team that either helped or presented challenges to getting the project's work done? (Possible Follow-up: How did you feel at the conference? Did you feel that you fit in? Could you see yourself becoming part of the land trust (conservation) community?)

**11.** What kinds of interactions in the team supported all in contributing to the team's work? Was there anything that kept members from contributing to the team's work? (Possible Follow-up: How did the team interact at the conference? Did all members participate?)

Part 6: Ways of Seeing and Being (Attitudes such as empathy, wonder, appreciation, respect toward natural world, conservation science and technology and actions such as ways of speaking, protecting, educating)

**12.** What, if any, changes has this project had on how you view the natural world or technology? (e.g., change in respect, empathy, appreciation, wonder) (Possible Follow-up: Have you had any conversations about conservation work or the technology you used with family or friends? Do you see yourself continuing to be involved in this type of work (i.e., conservation science or geospatial technologies)? If so, how? If not, why not?)

**13.** What, if anything additional would you like to share about your overall experience in this project?

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