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Assessing STEM identities in Intergenerational Informal STEM Programming

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Our research analyzed two years of data from a 5-year NSF-funded informal STEM (science, technology, engineering, and mathematics) program. Our program aims to support development and maintenance of STEM identities in intergenerational teams learning geospatial technologies and conservation science to develop and implement community land-use projects. The conservation science and technology identity (CSTI) surveys were developed as a potential method to characterize and quantify a person's STEM identity. The surveys examined five identity constructs for science and technology: competence, performance, external recognition, self-recognition, and ways of seeing and being. CSTI was administered before the workshop to evaluate the participants' historical STEM identity, and after to determine the workshop's impact on science and technology competences and ways of seeing and being. CSTI was also administered as a delayed-postsurvey after the year-long project was completed. This work is needed due to (a) the importance of the development and maintenance of STEM identity for persistence in engaging in science-related work, (b) the lack of reliable, quantitative measures supported by research on the constructs of identity, and (c) the need for development of empirical instruments to determine the impact of informal science learning programs on STEM identification.

Many people in the United States do not have positive experiences in STEM (science, technology, engineering, and mathematics) education that foster the development and maintenance of STEM identities throughout their lifetimes. STEM identity refers to a person's self-conception as someone who understands, uses, and contributes to a STEM field.

Many perspectives can be found as to what constitutes STEM education. Ellis et al. (2020) recognized consensus on four aspects of integrated STEM education: (a) incorporates real-world contexts to promote student engagement and meaningful learning (Bryan et al., 2015; Burrows et al., 2017; Kelley & Knowles, 2016; Sanders, 2009), (b) focuses on student-centered pedagogies (Bryan et al., 2015; Kelley & Knowles, 2016), (c) emphasizes developing 21st-century competencies (e.g., creativity, critical thinking, communication, and collaboration) (Bryan et al., 2015; Honey et al., 2014), and (d) makes explicit connections between STEM disciplines (Bryan et al., 2015; Burrows et al., 2017; English, 2016; Herschbach, 2011; Honey et al., 2014; Kelley & Knowles, 2016).

For this paper, STEM is understood as representing any of the individual fields in science, technology, engineering, and math. Of the four fields, technology is the one that lacks a clearly defined role in STEM education. Ellis et al. (2020) found that a technology perspective, where students use authentic STEM tools and techniques, had the greatest impact on learning science content and practices. This finding aligns with a definition of technology from the Project 2016 Phase I Technology panel report (Johnson, 1989) that defined technology as a process that applies knowledge, skills, and tools to solve problems (see also Ellis et al., 2020).

One of the greatest challenges in science teacher education is understanding how to design STEM programming that provides opportunities for positive experiences that promote identification with STEM fields. Developing a person's STEM identity can lead to increased participation and sustained engagement in these disciplines (Archer et al., 2010; Basu & Barton, 2007; Calabrese Barton et al., 2013; Carlone & Johnson, 2007; Stets et al., 2017). According to the National Research Council (NRC & Bell, 2009), "It is an important goal that all members of society identify themselves as being comfortable with, knowledgeable about, or interested in science" (p. 46).

The NRC's recommendation that learners in informal environments develop the capacity to "think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (NRC & Bell, 2009, p. 4) is theoretically and empirically grounded in the conceptualization of identity as connected to engagement in social contexts (Carlone, 2012).

A STEM identity is one type of social identity where one develops an affinity toward a STEM field. Gee (2000) described multiple types of identities people have throughout their lifetimes that are foregrounded depending on differing social environments and continually changing as a social process. 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 distinctive group practices.

Our research involved the continued development and implementation of the Conservation Science and Technology Identity (CSTI) survey, by which we sought to provide an empirical method to determine STEM identity profiles of informal science program participants. The STEM identity profiles were based on previously determined identity constructs of competence, performance, recognition, and a newly emergent construct, ways of seeing and being. The surveys provided a means for (a) making identity constructs empirically accessible, (b) revealing STEM identities of recruited participants in informal science learning opportunities, and (c) revealing the positive outcomes of participation for those taking advantage of informal programs like our workshop. Building on our previous research (Rodriguez et al., 2020), this paper presents the first 2 years of data from a multiyear study and was exploratory.

Our research is important as it supports the ability to characterize the historical STEM identities of those who access informal STEM programs and the impact of the program on their STEM identities. More specifically, the CSTI survey can assist programs in revealing the historical STEM identities of participants to determine if programs are effective in promoting newly forming STEM identities or supporting already well-established STEM identities. In other words, equity in informal science programs can be supported by empirically assessing STEM identity to determine program accessibility and effectiveness. This information is especially important, since if informal science programs are only accessed by students with already well-developed science identities these programs may serve to increase inequities for underrepresented students (Dawson, 2017; Feinstein & Meshoulam, 2014).

STEM Identity Authoring

The theoretical lens used to frame this research is STEM identity authoring, which evolved out of broader research on identity, specifically Gee's (2000) theory of multiple identities. Gee postulated that individuals have many identities that are continuously changing as a social process throughout their lifetimes. Different identities are foregrounded depending on different social situations (Varelas et al., 2011).

Lave and Wenger (1991) noted how "one way to think of learning is as the historical production, transformation, and change of persons" (pp. 51–52). Developing identities throughout one's lifetime is, in effect, learning as it encompasses a transformation and change of persons (see also Varelas et al., 2011). Developing a STEM identity refers to the ways individuals come to recognize themselves as feeling comfortable engaging in STEM pursuits and being around others who engage in similar pursuits. This identity includes seeing oneself as being able to understand science concepts, engage in science performances, and be recognized by others as belonging in that field (Carlone & Johnson, 2007).

Three factors found to contribute to identification with a STEM field are (a) competence – knowledge and understanding of core disciplinary concepts, (b) performances – engagement in disciplinary practices to accomplish consequential pursuits, and (c) recognition – acknowledging one's competences and performances and having others acknowledge them (Carlone & Johnson, 2007; Hazari et al., 2015). A fourth – emerging – construct examined in this research that may contribute to STEM identity authoring is ways of seeing and being – that is, the values, attitudes, and behaviors that result from immersion within a scientific discipline such as conservation science (Hill et al., 2017; Jaber & Hammer, 2016).

Competence

Science competences are scientific skills, knowledge, and understandings gained through education, training, or other salient experiences (Klieme et al., 2008) and should not be considered an intrinsic trait of individuals. Developing competence involves opportunities to participate in scientific performances and have those performances interpreted and recognized as demonstrating competence in scientific understandings (Carlone 2012; Carlone et al., 2011; Gresalfi et al., 2008).

A person's self-recognition of competence may be defined according to a priori definitions of what constitutes good science in a specific situation (Carlone 2012; Kelly et al., 1998). Group level meanings of competence are situational and determine who is recognized as competent or not (Carlone 2012; Gresalfi et al., 2008; Lottero-Perdue & Brickhouse, 2002). According to Erikson (1968), individuals are inclined to seek mastery in social interactions, but competence becomes part of identity only when it is recognized by meaningful others (Cote & Levine, 2002; Josselson, 1996) and internalized (Hazari et al., 2015). Further, and specifically related to this research focused on exploring informal learning spaces, McLaughlin et al. (2001) found that students who were unsuccessful demonstrating competence in formal learning environments – many from nondominant backgrounds – may have more success showing competence on the same content in informal learning spaces.

Performances

Performances are actions involved in creating and sharing new competences in scientific knowledge and understandings. Members of a group with common purposes and expectations develop specific practices for shared ways of talking and using tools (Carlone, 2012; Kelly, 2007; Lave & Wenger, 1991). Individuals with common interests and shared distinctive practices develop into affinity groups (Gee, 2000), or communities of practice (Wenger, 1998), where members may be more connected to the practices and experiences than to other members of the group. Often their membership is sustained through the practices.

Gee (2011) defined performance as "socially recognized and institutionally or culturally supported endeavor that usually involves sequencing or combining actions in certain specified ways" (p. 17). Scientific performances involve practices that support building explanations or solving problems and include investigative, communicative, and epistemic practices. Investigative performances are those of inquiry (e.g., observation, questioning, collecting and analyzing data, testing ideas, and developing solutions). Communicative practices are ways of sharing information and ideas. Kelly and Licona (2018) referred to epistemic practices as those used to make sense of phenomena (e.g., inferring, justifying, evaluating, and legitimizing scientific knowledge). These scientific performances constitute the act of doing science, which is at the core of being a scientist (Todd & Zvoch, 2017).

Recognition

The third construct found to be important in developing STEM identity is recognition. Recognition includes both recognition by others and self-recognition of competences and performances. Engaging in scientific performances provides opportunities for others to recognize an individual's competence in a STEM field (Barton et al., 2008; Carlone, 2004; Kang et al., 2019; Polman & Miller, 2010). Recognition can be positive feedback (e.g., praise, special privileges, or gifts) that acts to integrate STEM identity or negative feedback (e.g., criticism, slights, or penalties) that acts to inhibit STEM identity integration (Kerpelman et al., 1997; Todd & Zvoch, 2017).

For recognition from others to foster STEM identification, it must be internalized as self-recognition (Hazari et al., 2015). Recognition that depends on demonstrations of scientific competence and performances connects the constructs of STEM identity. Recognition of other identities, however, may work to promote or constrain identification with STEM fields (Archer et al., 2010; Brown et al., 2017; Carlone & Johnson, 2007; Ceglie, 2011).

Ways of Seeing and Being

The final construct, ways of seeing and being, is an emerging construct that needs further examination to determine what role, if any, it plays in STEM identification. Ways of seeing and being involves the reciprocating interaction between attitudes, values, and beliefs toward a STEM field (i.e., ways of seeing) that motivate a person's actions in that field (i.e., ways of being).

Ways of seeing and being adds the affective domain to demonstrations of competences and performances. Hill et al. (2017) proposed discovery orientation as a similar construct examining the affective domain of learning. Feelings of interest, curiosity, and the enjoyment of discovery were found to be important to science learning (Farrington et al., 2012; Trujillo & Tanner, 2014; Watt et al., 2012). Jaber and Hammer (2015) examined the link between epistemic affect – the feelings involved when engaged in science performances that come from knowledge building – and epistemic motivation – the desire to continue with these sense-making activities.

These two studies undergird the first half of this new construct (ways of seeing). Ways of being involves behaviors that reciprocally reinforce these feelings and motivations. Carlson (2010) looked at how immersion, participatory engagement, and struggle in nature affects a sense of aesthetic appreciation. To generalize to any STEM field, when a person is immersed in a field of science, participates in, and struggles to make sense of it, they develop an appreciation for that field of study. Ways of seeing and being combines these ideas and applies them to the development of STEM identity.

In the case of conservation science, when a person is learning about nature through participatory engagement (i.e., performances) to make sense of natural phenomena (developing competence), they develop certain attitudes, values, and beliefs, such as aesthetic appreciation (ways of seeing), that motivate them to take actions, such as engagement in projects, to protect or conserve natural areas (ways of being). Through their actions, the person develops a STEM identity in that field as they are recognized by others and themselves as being a certain kind of person (e.g., naturalist, conservation scientist, or environmentalist).

For each of these constructs, our research examined their relationship to identification with conservation science and technology. Further, in this current research, especially in the context of the conservation projects undertaken where the application of technology (e.g., geospatial and mapping technologies) was used extensively to support intergenerational teams' accomplishment of their pursuits, we also recognized the role technologies could play in shaping STEM identity authoring. Next is a review of the literature on STEM identity authoring in informal STEM programs

Literature Review

STEM Identity Authoring in Informal STEM Programs

The NRC (2009) described informal STEM learning (ISL) programs as places where all people, regardless of age or background, can explore science, technology, engineering, and math to develop their identification and agency in these fields. Identification with a field refers to how people see themselves as being able to understand, use, and contribute to the field. Agency is the capacity to act independently, make decisions and contributions to the field. McLaughlin et al. (2001) found that many learners who experienced failure in formal school science may demonstrate competence in informal settings. The NRC further detailed two goals of ISL programs: (a) to develop and nurture STEM identities, and (b) to increase participation by historically underrepresented populations in STEM.

Bell et al. (2017) recognized the need for ISL programs to be designed intentionally to promote practice-linked identification. ISL programs have many features that contribute to their potential to promote STEM identification. Dierking et al. (2003) discussed the correlation between participant choice and participant needs and interests. Learners often choose ISL programs because they are already interested in the subject, or they recognize a need to learn more about aspects of the field. ISL programs are attractive to many learners because they are often learner-motivated, open-ended, and collaborative (Falk & Dierking, 2000; Griffin, 1998).

Many ISL programs emphasize increasing motivation and confidence over factual knowledge (Fields, 2007; Johnsen, 1954). Other features of ISL programs that may influence the development of participants' STEM identities are (a) unique locations, (b) authentic projects that promote exploration and curiosity, (c) apprenticeship models based on inquiry and hands-on activities (Barab & Hay, 2001; Gibson & Chase, 2002; Markowitz, 2004; Sondergeld et al., 2008), and (d) access to scientists and specialized equipment (Barab & Hay, 2001; Markowitz, 2004; Robbins & Schoenfisch, 2005).

ISL environments have been found to promote STEM identification in underrepresented groups who may not have engaged in disciplinary practices in formal science spaces. Many girls have been found to lack opportunities to engage in science practices in school (Alexander et al., 2012; Hill et al., 2010; Jovanovic & King, 1998; Tan et al., 2013), but when engaged in informal science, they have been found to develop science identities (see also Todd & Zvoch, 2017).

Measuring STEM Identity

Development of a STEM identity has been conceptualized with both intrinsic and extrinsic factors (Aschbacher et al., 2010), reflecting cognitive and social constructs. This conceptualization has led to a variety of methods of assessing STEM identities. Much of the research on STEM identity has used qualitative methods, which provide a rich understanding of identity as a social construct (Carlone & Johnson, 2007; Herrera et al., 2012; Sfard & Prusak, 2005). Intrinsic factors such as interest (Hazari et al., 2010), self-efficacy, and competence beliefs (Eccles et al., 2015), as well as extrinsic features such as participation (Crowley et al., 2015), recognition, sense of community, and affiliation (Carlone & Johnson, 2007) are all thought to be involved (Vincent-Ruz & Schunn, 2018) and present a variety of features to measure.

Researchers have attempted to quantify aspects of STEM identity through various methods (McDonald et al., 2019; Starr, 2018; Young et al., 2013). McDonald et al. (2019) developed a single-item STEM professional identity overlap measure for assessing STEM identity emphasizing typicality. STEM Typicality refers to how much a person feels similar to people who work in STEM fields (Tobin et al., 2010). McDonald et al.'s assessment looks at the overlap between students' perception of themselves and STEM professionals. While the measure has been able to differentiate between majors and nonmajors in STEM, it lacks the nuances of examining individual constructs and how they may intersect.

Hazari et al. (2015) also focused on typicality by asking students whether they see themselves as a biology, chemistry, or physics person. One issue with this study is its suggestion that the construct of science identity is static, conceived of as an all-or-nothing proposition, and being a scientist cannot be learned (McDonald et al., 2019). In a different approach, Young et al. (2013) created a multi-item scale examining the importance of science to one's self-concept. Their main objective was to see the effect of female science professors on the science cognitions of female undergraduates, including attitude, identification, and stereotypes. Their survey was specific to their goal and not meant to measure individual constructs of STEM identity.

Vincent-Ruz and Schunn (2018) examined the role of science identity on middle and high school student participation in optional science experiences. Their survey examined only two constructs, self-recognition as a science person, and recognition from others. While previous studies have assessed different aspects of STEM identity, none have sought to measure all the constructs included in our CSTI survey or to develop identity profiles.

Purpose and Research Questions

In our previous research (Rodriguez et al., 2020), we recognized the value in developing a survey instrument that could empirically assess a person's STEM identity as a tool for informal science learning researchers and programmers (i.e., individuals who plan and lead ISL programs). More specifically, we identified the need for the CSTI survey we developed in relation to (a) the importance of the development and maintenance of a STEM identity for persistence in engaging in science-related work (Carlone & Johnson, 2007), (b) the lack of reliable, quantitative measures supported by research on the constructs of identity, (c) the value of empirical instruments to help determine who is accessing informal STEM programs, and (d) the impact of informal science learning programs on STEM identification.

While our initial research helped us to provide early evidence of the promise of the CSTI survey, we recognized how this current research would be important to further explore the reliability and functionality of the survey. Research Question 1 addressed the further testing of the instruments: How does an increase in sample size (n) affect the reliability of the instrument?

We also wanted to begin exploring what the survey could help us understand about our informal STEM learning program. Our overarching question was, How can the conservation identity instruments inform ISL programmers of the effects of their programs on the STEM identity of participants? This question includes whether the STEM identity characterizations of participants were different across the different sites where we held our workshops and about ways STEM identity constructs might change over time from our participants' engagement in long-term conservation projects.

Research Questions 2-5 addressed our overarching question:

> 2. What can the pre-workshop surveys tell us about how the historical science and technology identities of adults and teens participating in the workshops compare?
>
> 3. What can the surveys tell us about how the participants' STEM identities at different sites compare across the 2 years?

4. How do four identity constructs (i.e., science and technology competence, and science and technology ways of seeing and being) compare from pre- to postsurvey?

5. How do all identity constructs compare from pre- to delayed postsurveys?

Methodology

Research Context and Design

This research is part of a larger project funded by the National Science Foundation advancing informal stem learning (AISL) aimed at studying STEM identification in teens and adults working in intergenerational partnerships on authentic conservation projects. This project is a collaboration between the natural resources department, center for land-use education, and school of education in a large public university in the northeastern United States, in which we developed and implemented 2-day workshops on conservation science and geospatial technologies.

In the workshops, high school teens were paired with adult community partners and supported in developing collaborative community conservation projects over the year. The projects culminated in poster presentations at local and state conservation conferences. One goal of this study was to continue to develop and test the empirical instrument (i.e., CSTI survey) that we developed and reported on in our earlier research (Rodriguez et al., 2020).

The first research question addressed the goal of further testing the instruments' reliability. Research Questions 2-5 guided examination of the use of the instruments to reveal how the constructs of STEM identity intersected in the participants' historical STEM identities and how these constructs may be affected by an informal science learning program. To this end, the CSTI surveys were administered to high school students and their adult partners three times: (a) before the workshops, (b) after the workshops, and (c) at the conclusion of their community project. To answer Research Questions 2 and 3 we used a pretest-only design comparing historical STEM identity constructs between adults and teens and site locations. To answer Research Questions 4 and 5, we compared constructs over time and used a repeated measures design (Kraska, 2010).

The workshops aimed to promote mutual learning through instructional modules and field experiences in conservation science and geospatial technologies in preparation for the intergenerational partners to design and implement community-based conservation projects (Chadwick et al., 2018; see Appendix: Workshop Agenda). The workshops and overall program are explained in the STEM for all 2019 video at this link: https://stemforall2019.videohall.com/presentations/1465 (Rodriguez et al., 2019).

In the workshops, the partners explored conservation science concepts such as changes in (a) land-use, (b) forest health, (c) water resources, and biodiversity while learning how to use online mapping tools (Chadwick, et.

al., 2018). Field activities included learning geospatial technologies such as epicollect, a mobile data gathering app to collect and organize water quality data from nearby streams, and Track Kit, a smartphone app that drops waypoints as you walk creating a trail map and allows users to add photographs to the waypoints. The data can then be uploaded to Google Maps to create an interactive trail map. A list of mapping tools used in the workshops and projects are at the website Maps & Apps for Community Conservation Project (https://uconnclear.maps.arcgis.com/apps/MapSeries/index.html?appid=ddb72c20c2074562aec32682d8350be5). Final projects are posted on the University of Connecticut Conservation Training Partnerships website (https://nrca.uconn.edu/students-adults/projects.htm).

The delayed posttest mirrored the pretest and was administered after participants concluded their projects with a conference presentation. The aim of administering the delayed postsurvey was to provide additional data on the impact of engagement in the yearlong community conservation project on the intergenerational partners' STEM identities. Figure 1 illustrates how the research design aligns program goals, research questions, and data analysis.

Setting and Participants

This study examined data from five workshops during the first 2 years of the program. The workshops were held at five different sites across a New England state, two the 1st year and three the 2nd. The first workshop took place in a rural area in the eastern region and the second in an urban area in the south-central section. The third workshop took place in a rural western area, the fourth in an urban central area, and the fifth in a rural northwestern section.

Ninety-eight participants, 44 adults and 54 teens, from 54 towns in the focal state and two neighboring states attended the workshops. Teen participants were recruited through high school science teachers and counselors and nonprofit youth service organizations. Adult participants were recruited through land trusts, conservation commissions, and nonprofit environmental organizations. Fifty percent of the participants were female, 78% were White, 11% were Black, 9% were Asian American, and 6% were Latinx. The teens came from 13 high schools and the adults represented 14 conservation groups. Adults ranged in age from 30 to 73 (Table 1).

Figure 1
Research Design Logic Model

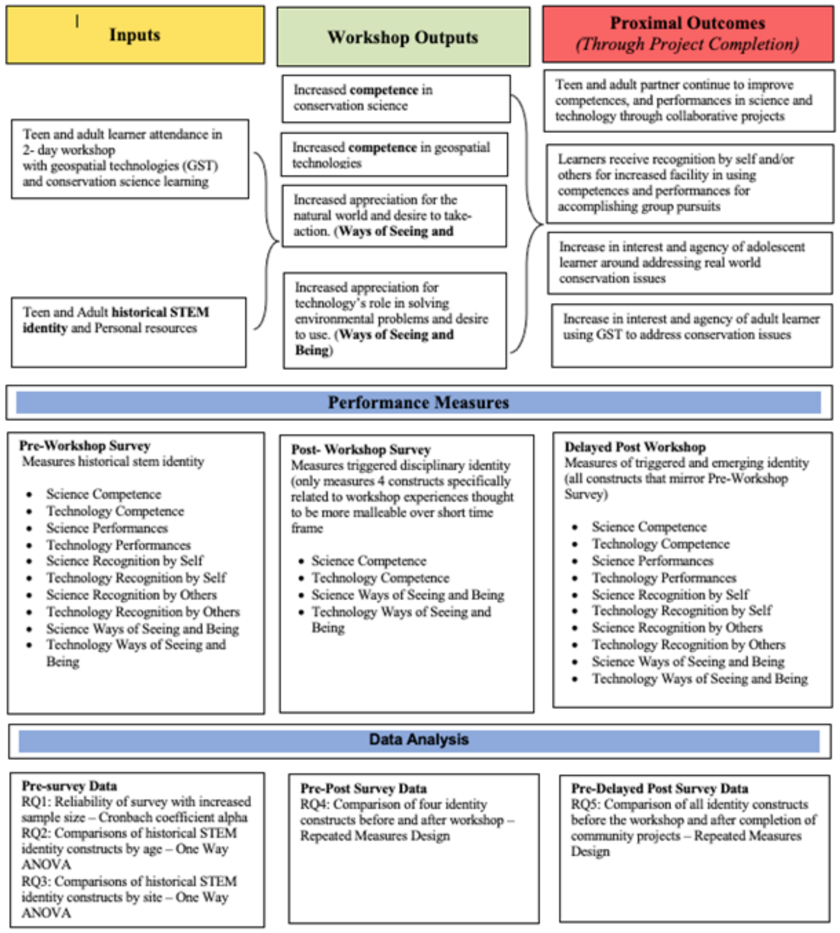


Table 1
Demographics of Participants by Workshop Year

Participants	Adults Year 1	Adults Year 2	Teens Year 1	Teens Year 2
N	15	29	17	37
% Female	60	66	53	32
% White	80	79	71	65
% African American	7	7	12	14
% Latinx	0	7	0	11
% Asian American	0	0	12	8
% More than 1 Ethnicity	0	0	12	0
% Not designated	7	7	0	3
% Rural	20	48	29	32
Suburban	67	45	65	49
Urban	13	3	7	11

Study Instruments

This study is a continuation of a previous pilot study from the 1st year of implementation of the CSTI instruments described in Rodriguez et al. (2020). The development of the instrument involved an eight-step process:

1. Category development adapted from the literature on science identity.
2. Addition of technology categories.
3. Formation of an item pool for science constructs, followed by the formation of a comparative item pool for technology constructs.
4. Vetting from national experts on STEM identity research to establish content validity.
5. Vetting from our external evaluator on the structure and wording of the instrument to reduce bias.
6. Modification and reduction of item pool to four for each construct based on reviewer comments.
7. Comparison of construct items among pre-surveys, post-surveys and delayed-post surveys.
8. Finalization of all instruments and modification to an online format.

The presurvey for teens was finalized with 40 Likert-scaled items. The Likert scale for questions on competence used the following rating: 1 = *No Understanding*, 2 = *Little Understanding*, 3 = *Fair Understanding*, and 4 = *Strong Understanding*. All other constructs used the following Likert scale responses: 1 = *Strongly Disagree*, 2 = *Somewhat Disagree*, 3 = *Somewhat Agree*, and 4 = *Strongly Agree*.

The presurveys had four questions for the 10 constructs related to STEM identification (i.e., competence, performances, external recognition, self-recognition, and ways of seeing and being), five for conservation science, and five for technology. The postsurvey contained questions related only to four constructs (i.e., science competence, science ways of seeing and being, technology competence, and technology ways of seeing and being) thought to be more malleable over the short time frame between pre- and postsurveys.

A delayed post-survey was also developed to be administered after the yearlong project mirroring exactly the presurvey. The adult surveys were modified with only minor changes to accommodate their different life stage. For example, questions about school experiences were written in past tense rather than present.

This study extended our previous research by determining how an increase in sample size might affect the reliability of the instrument and participant results and included data from the delayed postsurvey. The increase in the number of workshop locations allowed for an additional question to be explored about the effects of workshop location on historical STEM identity of the participants.

Analysis Design

To answer the first research question, we used the internal test of reliability, Cronbach coefficient alpha. The second analysis strategy, used to answer the second research question, involved determining the descriptive statistics for teen and adult CSTI surveys and using One Way ANOVA comparing STEM identity constructs with age. For Research Question 3, One Way ANOVA was used to compare STEM identity constructs for the five workshop locations. Repeated Measures Design looking at between-subject factors (age and site) was used to answer Research Questions 4 and 5. For Research Question 4, only four constructs (i.e., science and technology competence, and science and technology ways of seeing and being) were compared in the pre- and postsurvey results. For Research Question 5, all constructs were compared in the pre- and delayed postsurvey results.

Findings

The findings section is organized by the five research questions.

Finding 1: Reliability

Findings suggest the CSTI instrument is valid, reliable, and appropriate for future use, both in the subsequent phases of our current research and as a resource for others. The sample size increased from 44 participants the first year to 98 participants combining both years. Cronbach coefficient alpha increased for all but two constructs (technology performance and self-recognition) with the larger sample size. With the combined data from the 2 years, all constructs had a Cronbach alpha coefficient > 7.00, which is considered an acceptable level of internal consistency (Nunnally & Bernstein, 1994). (Insert Table 2)

Table 2
Cronbach Coefficient Alpha for Both Years Combined

Participants	Adults Year 1	Adults Year 2	Teens Year 1	Teens Year 2
N	15	29	17	37
% Female	60	66	53	32
% White	80	79	71	65
% African American	7	7	12	14
% Latinx	0	7	0	11
% Asian American	0	0	12	8
% More than 1 Ethnicity	0	0	12	0
% Not designated	7	7	0	3
% Rural	20	48	29	32
Suburban	67	45	65	49
Urban	13	3	7	11

Finding 2: Comparisons

All participants scored significantly higher on the prescience portion than the pretechnology portion. Significant differences were also found in overall science identity constructs between teens and adults ($F = 4.757$, $p = .032$). Adults scored significantly higher on the prescience portion than teens. Looking at the scores on individual constructs, we found significant differences in the mean scores for: science competence ($F = 9.513$, $p = .003$), science performance ($F = 7.699$, $p = .007$), and technology self-recognition ($F = 5.581$, $p = .020$). Adults scored higher on the two science constructs (Figure 2) while teens scored higher on the technology construct (Figure 3).

Figure 2
Adult vs. Teen Prescience Identity Constructs

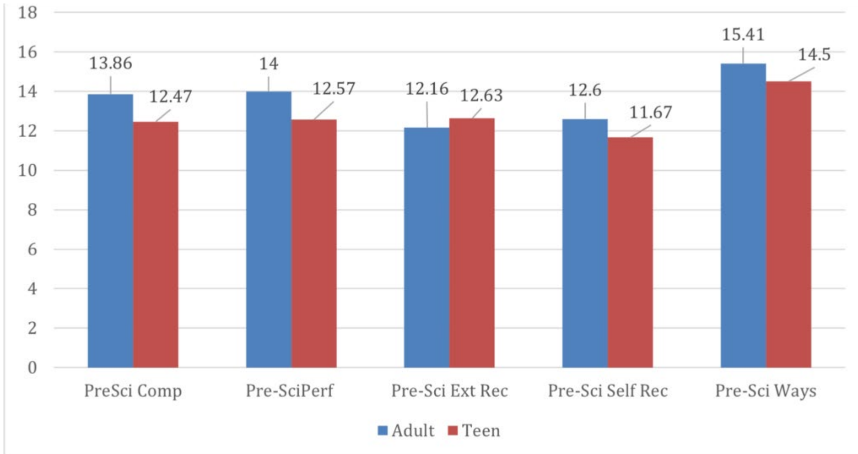
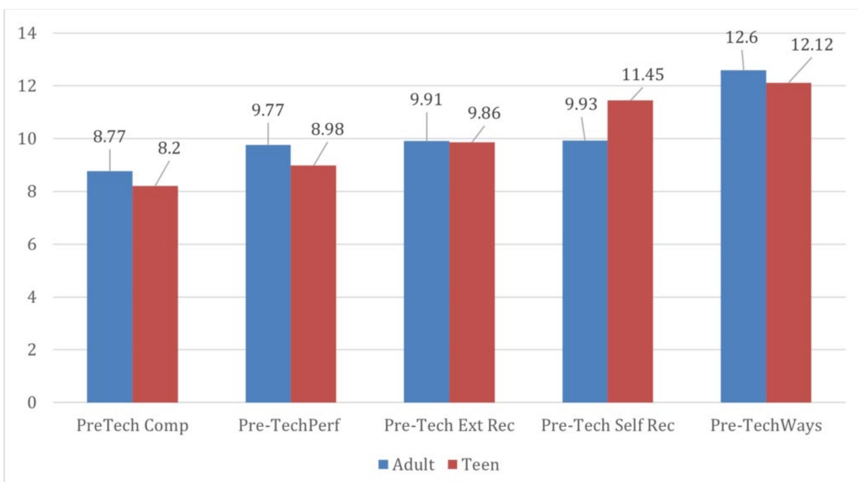


Figure 3
Adult vs. Teen Pretechnology Identity Constructs



Finding 3*:* Historical STEM Identity by Workshop Site

A one-way ANOVA was performed to examine any difference in the mean presurvey scores of participants from the five sites where the CTP workshops were held. No significant difference was found in overall mean scores between participants in the five locations. Also, no significant differences were found in overall prescience constructs and pretechnology constructs or any of the individual constructs by site location (Table 3).

Table 3
Comparison of STEM Identity by Workshop Location

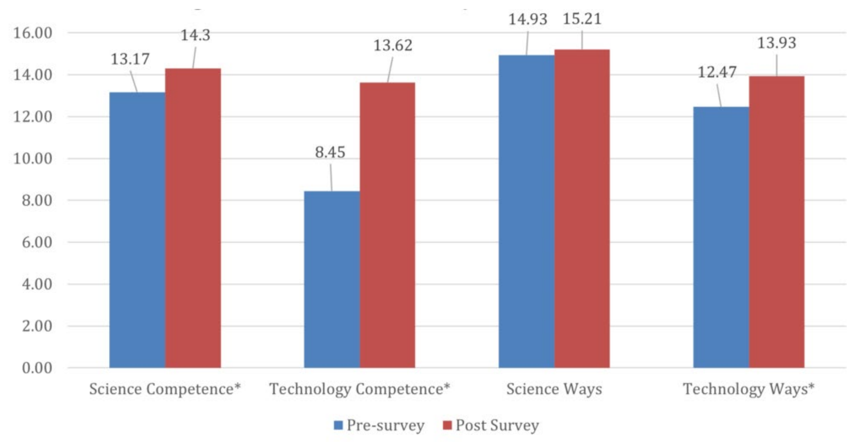
Presurvey Comparisons	Site 1 Mean	Site 2 Mean	Site 3 Mean	Site 4 Mean	Site 5 Mean
Overall STEM Identity	118.00	114.50	117.00	114.16	119.00
All Science Identity Constructs	67.35	65.87	65.47	62.96	67.80
All Technology Identity Constructs	50.65	48.67	51.53	51.20	51.30
Science Competence	12.88	13.13	13.47	12.80	13.35
Science Performance	13.59	13.53	13.41	12.40	13.55
Science External Recognition	13.24	11.67	11.47	12.44	13.05
Science Self-Recognition	12.59	12.00	12.35	11.16	12.70
Science Ways of Seeing and Being	15.06	15.53	14.76	14.16	15.15
Technology Competence	7.76	7.40	9.00	8.72	9.05
Technology Performance	9.24	9.60	9.41	9.32	9.20
Technology External Recognition	10.71	8.47	9.65	10.32	9.90
Technology Self-Recognition	10.82	9.87	11.53	10.80	10.65
Technology Ways of Seeing and Being	12.12	13.33	11.94	12.04	12.50

Finding 4: Identity Construct Increases Pre-Post

A one-way repeated measures analysis of variance (ANOVA) was conducted to evaluate the null hypothesis of no change in participants' survey scores for the four STEM identity constructs included in both pre- and postsurveys (i.e., science competence, technology competence, science ways of seeing and being, and technology ways of seeing and being). A significant increase was found in the overall mean scores between pre- and postsurveys, Wilks lambda = .314, $F\,(1,77) = 168.023$, $p < .001$, partial eta = .686, power = 1.000.

Three out of four of the individual constructs also had significant increases in mean score in the postsurvey: science competence, Wilks lambda = .876, F (1,77) = 10.906, p = .001, partial eta = .124, and power = .903; technology competence, Wilks lambda = .322, F (1,77) = 162.017, $p < .001$, partial eta = .678, power = 1.00; and technology ways of seeing and being, Wilks lambda = .880, F (1,77) = 10.502, p = .002, partial eta = .120, power = .892; see Figure 4). No significant differences were found between age groups or locations.

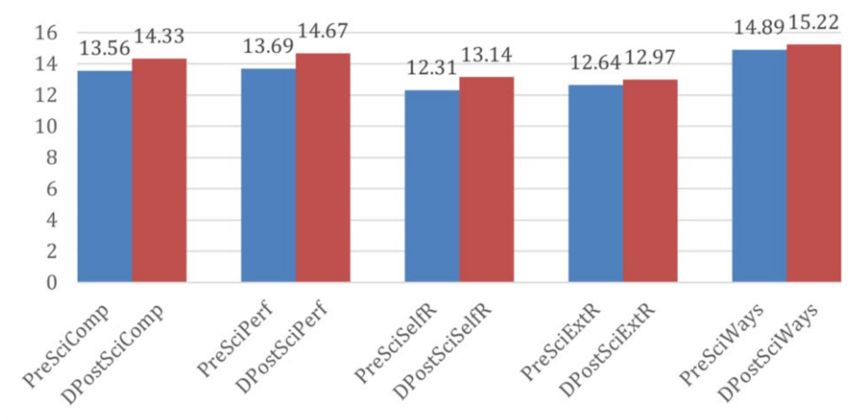
Figure 4
Pre- vs. Postsurvey for Four Constructs



Finding 5: Construct Increases Pre- to Delayed Post

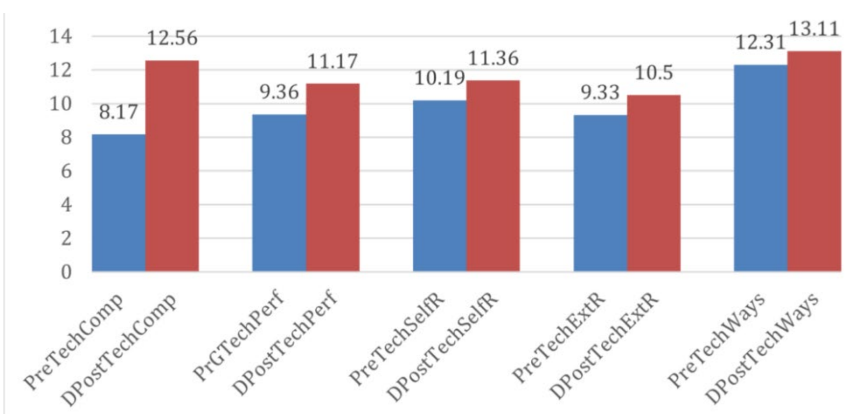
Although only 36 of the 98 participants completed the delayed postsurvey, all mean science identity constructs significantly increased from pre- to delayed postsurvey except science external recognition and science ways of seeing and being (Figure 5).The scores for science ways of seeing and being were negatively skewed. All participants scored close to the highest possible score of 16. The scores could not be transformed into a normal curve to see if the increase was significant. The mean scores for science competence increased from 13.56 to 14.33 (Wilks lambda= .761, F = 10.650, p = .003, partial eta = .239, power = .877). Mean science performance increased from 13.69 to 14.67 (Wilks lambda = .636, F = 19.431, $p < .001$, partial eta = .364, power = .990). Mean science self-recognition increased from 12.31 to 13.14 (Wilks lambda = .777, F = 9.755, p = .004, partial eta = .223, power = .859). While mean science external recognition increased from 12.64 to 12.97, the increase was not significant (Wilks lambda = .972, F = .985, p =.328, partial eta = .028, power = .162).

Figure 5
Pre- vs Delayed Postsurvey Identity Construct Mean Scores



All mean technology scores significantly increased from pre- to delayed postsurvey (Figure 6). Mean technology competence increased from 8.17 to 12.56 (Wilks lambda = .261, *F* = 96.407, *p* < .001, partial eta =, .739, power = 1.000). Mean technology performance increased from 9.36 to 11.17 (Wilks lambda = .489, *F* = 35.468, *p* < .001, partial eta = .511, power = 1.000). Mean technology self-recognition increased from 10.19 to 11.36 (Wilks lambda = .700, *F* = 14.551, *p* = .001, partial eta = .300, power = .959). Mean technology external recognition increased from 9.33 to 10.50 (Wilks lambda =.750, *F* = 11.352, *p* = .002, partial eta = .250, power = .905). Mean technology ways of seeing and being increased from 12.31 to 13.11 (Wilks lambda = .792, *F* = 8.913, *p* = .005, partial eta = .208, power = .826).

Figure 6
Pre- vs Delayed Posttechnology Identity Construct Mean Score



Discussion

Like the Findings section, the Discussion section is organized by the research question. More specifically, findings for each research question are discussed by (a) making a claim for each research question developed from data analysis, (b) justifying each claim, and (c) considering our findings in light of this study's context and the existing literature.

Reliability

We found that continued testing of the CSTI instruments supports earlier research that the instrument is a reliable measure of STEM identity. One goal of our larger funded project was to develop a valid, reliable, quantitative instrument that could give insight into the historical STEM identities of participants who access informal STEM programs. Our instrument was designed to provide information about established intersecting identity constructs (Carlone & Johnson, 2007; Hazari et al., 2015, Carlson, 2010, Jaber & Hammer, 2016) that comprise a STEM identity. In Year 1, we focused on (a) developing the instrument and establishing content validity through a vetting process by experts in the field of science identity and (b) analyzing internal reliability with Cronbach coefficient alpha (Rodriguez et al., 2020). In Year 2, we continued evaluating the instrument with a larger sample size to establish a better reliability estimate using Cronbach coefficient alpha.

All measures of internal reliability improved with a larger sample size, suggesting CSTI is a valuable resource for characterizing a person's identification with the STEM fields of conservation science and technology and is appropriate for future use in our research and as a resource for informal science learning researchers and programmers, as no equivalent survey exists.

Comparisons

The CSTI instrument enabled comparisons of individual STEM identity constructs between adults and teens. Our results found no significant differences between overall teen and adult historical STEM identities but did find significant differences in individual constructs. This finding highlights the importance of examining individual constructs in addition to overall STEM identity.

We found adults rated themselves higher in science competences and performances than did teens. Participating in scientific performances has been linked to the development of competence in scientific understandings (Carlone, 2012; Carlone et al., 2011; Gresalfi et al., 2008). The higher adult scores in these two constructs were anticipated, as adults who chose to participate in this program had more opportunities in connection to education, training, or other salient experiences that contribute to the development of competence, especially when compared to teens (Klieme et al., 2008). Interestingly, the adults did not rate themselves higher than the teens in conservation science self-recognition or recognition from others.

The teens rated themselves higher in technology self-recognition, although not in technology competence and performances. While we predicted the teens would rate themselves higher in the technology constructs than the adults would, due to perceptions that young people are more competent with technology than older adults (Vaterlaus et al., 2015), this was the only construct with a significant difference.

These results indicate a disconnect in participants' answers to questions about competences and performances and questions about self-recognition of those competences and performances. A person's recognition of their competence may be influenced by prior conceptions of what is considered good science in a particular situation (Carlone, 2012; Kelly et al., 1998). Participants may answer questions about specific competences differently than how they see themselves as competent in a field of science. This disconnect between ratings in competence and performances and self-recognition needs to be further explored.

Hazari et al. (2015) discussed how studying only external performances in trying to understand identity development can result in a mismatch between recognition by others (i.e., the observer) and internal designations (i.e., self-recognition) and recommended following up with surveys and interviews. When looking at self-reported survey data, follow-up interviews could provide data to resolve these discrepancies.

Workshop Location

Our findings indicate there were no significant differences in STEM identities between the participants at the different workshop locations. The five sites were chosen to include diverse population patterns (i.e., urban, suburban, and rural) in different geographic regions (i.e., northwest corner, southwest corner, central, eastern, and southeast corner) across the New England state where this research took place. Urban and rural areas have higher underrepresented populations in STEM than suburban areas (NRC, 2009). Still, each workshop attracted participants with similar STEM identity profiles.

In all workshops the historical STEM construct with the highest mean score was science ways of seeing and being. This result suggests that participants self-selected to take part in this program because they had already developed values and attitudes (i.e., ways of seeing) that made them want to get involved in conservation work in their communities (i.e., ways of being). They chose to get involved in a program where they would work on a community project over the course of a year.

This finding may overlap with research showing participation in informal science learning programs has been mostly those from advantaged groups (Dawson, 2014a, b; Dawson, 2017; National Science Foundation, 2012; OECD, 2012). This population often comes to informal science programs with already well-developed interests, (Lipstein & Renninger, 2006; Renninger & Hidi, 2002; Renninger et al., 2004) and the monetary resources to engage in projects unrelated to earning income.

Another factor affecting the results of workshop location is that the workshops were marketed across the state with no regional restrictions. Some participants chose to travel across the state to participate in a more conveniently timed workshop, so the workshops did not necessarily draw from the communities in which they were located.

Identity Constructs

Most identity constructs significantly increased over the course of the program. The informal science learning program in which this research was nested had two main short-term curricular goals for the workshop: (a) to increase competence in conservation science and the application of technology and (b) to increase an understanding of the value of using technology to help understand conservation issues and solve community problems. Two longer-term goals were to promote STEM identity authoring and increase understanding and engagement in community conservation work.

All constructs but one increased over the length of the program, suggesting the program contributed to strengthening the participants' STEM identities. The one construct that did not increase was science ways of seeing and being, which was highly negatively skewed in the pretest (i.e., all scores close to the highest possible score.) This ceiling effect makes it difficult to increase the mean score significantly.

Most participants arrived at the workshops with a strong aesthetic appreciation for nature (ways of seeing) and the desire to protect and preserve natural areas (ways of being). This skewed score may indicate that our program attracted only participants who already had positive experiences in conservation science. This finding echoes concerns that informal programs may serve to increase inequities for underrepresented students when they are accessed only by those with already well-established STEM identities. (Dawson, 2017; Feinstein & Meshoulam, 2014). It also suggests a need to reexamine recruitment strategies to attract diverse students without prior experiences in conservation science.

Science external recognition increased, though not significantly. Recognition of competence and performances has been found to be important for the development of STEM identity (Barton et al., 2008; Carlone, 2004; Kang et al., 2019; Polman & Miller, 2010) but only if the recognition is positive (Kerpelman et al., 1997; Todd & Zvoch, 2017) and internalized (Hazari et al., 2015). Negative recognition of learners' other identities can interfere with how learners identify with STEM (Archer et al. 2010; Brown et al., 2017; Carlone & Johnson, 2007; Ceglie, 2011). Although a positive finding, the way participants were recognized, by whom, and for what needs further exploration.

Overall, by the end of the program, participants indicated (a) a stronger understanding of conservation science and technology, (b) a greater ability to engage in conservation science and technology performances, (c) an increase in their self-recognition of science and technology competences and performances and (d) an increase in their view of the value of using technology in conservation pursuits.

Conclusions and Implications

Our research, as part of a larger informal science learning program, sought to understand how intergenerational partnerships working on community conservation projects affected the development and maintenance of STEM identities. One of the most important goals of science teacher education is to develop and maintain identification with STEM disciplines for learners to cultivate an interest in STEM into lifelong agency in STEM pursuits of consequence.

This research is important as it presents a way to empirically determine participants' level of identification with specific STEM fields as they enter an ISL program while allowing for pre/post comparisons to determine the effectiveness of the program. The CSTI Instruments provide a means: (a) of making STEM identity constructs empirically accessible to researchers and practitioners, (b) of revealing STEM identities of recruited participants to address recruitment strategies leading to inequities, and (c) of revealing positives outcomes of participation in informal science learning opportunities to evaluate program effectiveness.

This study showed (a) the CSTI instruments increased in reliability with an increase in sample size from 2 years of data, (b) differences in the identity constructs comprising the historical STEM identities of adult and teens, (c) no differences in historical STEM identities of participants at the different workshops, (d) increases in STEM identity construct scores from pre- to posttest for all but one construct (ways of seeing and being), and (d) increase in all identity constructs from pre to delayed post survey.

Although we increased recruitment of racially diverse participants in the 2nd year, our recruitment efforts fell short of enlisting significant numbers of participants with less developed STEM identities. The ability to determine a person's STEM identity is essential for promoting equity in informal science education and informing program designers of the effectiveness of the program and is also valuable for classroom teachers in evaluating growth in STEM identification of their students through the school year and across school years. The CSTI instruments enabled a more nuanced quantitative examination of STEM identity by helping make more apparent the influence of each individual STEM identity construct.

Limitations

Limitations of this study included sample size, the varying time frames between pre- and delayed postsurveys, and a relatively homogeneous cohort concerning STEM identity. The data for this study was from the first 2 years of a multiyear program. While the sample size for the pre- and postsurveys increased with 2 years of data (n = 97) from the initial 1st year study (n = 37), it was still small enough to warrant caution in making more generalizable claims and points to the exploratory nature of this study. Also, the sample size for comparing pre- and delayed postsurvey was smaller (n = 36), again limiting the strength of our claims until more data can be collected.

Participants had varying timeframes for working on their community projects. The time between attending the workshop and presenting their final projects at a conservation conference varied from 6-9 months, depending on the date of each workshop. Even though some participants were engaged in completing their projects over a shortened timeline, eight out of 10 STEM identity constructs significantly increased, indicating that differences in timespan of the project was not a significant factor in increasing identification with conservation science and technology. While ethnic and racial diversity of the participants increased from the 1st to 2nd year of the study (Table 2), the STEM identities of the participants remained fairly homogeneous. Participants entered the program with already well-developed STEM identities, but even so, the delayed postsurvey indicated an improvement in most constructs of STEM identity.

Author Note

The authors declare that they have no conflict of interest. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. This research was funded by National Science Foundation Grant No. AISL1612650.

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Appendix

Coding Scheme for Engineering Design Activity Analysis (Adapted from Atman et al., 1999; Wendell, 2014)

Code	Meaning	Example
Design Acclivities		
Problem Definition (PD)	Define what the problem is, including stating constraints, identifying criteria, and identifying sub-problems	"Why does this one keep turning like this? Which one is supposed to turn? [something kept turning]"
Gathering Information (GATH)	Look for information to solve the problem and discuss the information they gathered	"[reading the manual] Assemble to the DC motors. Does that take a special screw? Yes. It does
Generating Ideas (GEN)	Generate ideas to solve the problem	"But that means its RC [Remote Control] 2 and it's not in the 2. I think it's supposed to be 7."
Modeling (MOD)	Detail how to develop problem solution. It includes estimating something and making a part fit into the design.	"Yes, but the 2 by 1s [L frames] won't work because it is supposed to like go through, but it won't."
Making (MAK)	Decorate, assemble, and program robots	"Wheel guide… [keep searching for a proper part to assemble the wheel guide] Is this okay? [talking to herself]"
Feasibility Analysis (FEAS)	Judge whether the potential solution will work.	That one [robot] looks really easy.
Evaluation (EVAL)	Compare solutions, test a design, and evaluate the results	"I think the arms are just backward."
Decision (DEC)	Select or eliminate one solution	"Alright. We are going to do the jet bot."
Design-Related Conversational Moves		
Revoicing (REV)	Restate one's idea or understanding	Speaker 1: "And then the last one [the last button on the remote control] would be, forward. Because we only have 5 buttons." Speaker 2: "Forward. The go." Speaker 1: "So it's forward, each of the lights, each of the individual lights, and then all three lights."
Requesting (REQ)	Ask for clarification about an idea or design detail.	Speaker 1: "The left motor, the right motor, and. So the left motor goes to Port 1." Speaker 2: "In port 1?"

Agreement (AGR)	Agree with a partner	Speaker 1: “We will do recycling. We can make it walk. I’m just saying out.” Speaker 2: “You know… I like it.”
Disagreement (DIS)	Disagree with a partner	Speaker 1: “But like the back part goes this way, to this motor [looking at the manual]. You see? That flipped, like the other way.” Speaker 2: “No, it’s this way.”
Respond (RESP)	A response to a teammate that did not simply show agreement or disagreement	Speaker 1: “Do we have buttons or do we have a remote control?” Speaker 2: “Remote control.”
Respond to Instructor (RtI)	Responded to instructor when the instructor asked them questions about their problems or design during their help seeking	Speaker 1: “Why does the left motor only have two and right motor have three?” Instructor: “Maybe you put a stepper motor on instead of a regular motor.” Speaker 1: “Yes, we did.”
Other (OTH)	Conversation not relevant to the problem being solved	“Yeah! You’re the master of the programmer. I’m just a muscle. Hahaha.”