NOVICE BEHAVIOR IN A MAKERSPACE: PRAGMATIC PATHWAYS TO SHAPING CS IDENTITY

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DONALD GIBBS DAVIS, M.ED.

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COMMITTEE MEMBERS:
Timothy Yuen, Ph.D., Chair
Lee Mason, Ph.D.
Matthew Berland, Ph.D.
Vittorio Marone, Ph.D.
John Quarles, Ph.D.

THE UNIVERSITY OF TEXAS AT SAN ANTONIO
College of Education and Human Development
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DEDICATION

For my parents, without both of whom, this would not have been possible.
The gifts that my parents gave me are visible in equal parts in this dissertation.
My mother, Eleanor Anne b. Spiller, an elementary school teacher, gave me a love of learning, a love of teaching, insatiable curiosity, and my verbosity.
My father, Ron Davis, an electrician and all around do-it-yourselfer, gave me a love of using tools, a love of building things, and the inclination to try and fix almost anything.

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Donald Gibbs Davis, Ph.D.
The University of Texas at San Antonio, 2017

Supervising Professor: Timothy Yuen, Ph.D.

The behavioral investigation presented here provides initial behavioral insight into novice interactions occurring within a makerspace. Specifically, this dissertation represents an attempt to identify interactions that support nascent maker and computer science identity and skill behaviors. The data and discussions are provided in order to illuminate relations among physicality, identity, and novice behaviors within a makerspace. The discussion builds primarily on the conceptual bases of behaviorism, relational frame theory, behavioral phenomenology, and radical embodied cognition.

Through the use of a behavioral framework, the findings presented here shed new light on constructivist approaches to learning. *Social context matters*. The social environment provides the necessary structure for learning to happen at a makerspace. Tools alone cannot provide a makerspace or make learning happen. *Nonetheless, tools are important.* Tools provide a hook, a purpose, a context for people to gather and construct knowledge and artifacts. *Interactional histories matter*. Students' lives outside of the makerspace influence what happens in the makerspace. Students' susceptibility to reinforcement from maker-initiatives will be determined by how they relate to makerspaces, makers, and CS. If makerspace components are to be used effectively to broaden CS participation, it will be necessary to purposefully design learning trajectories for identity behaviors as well as conceptual skills.

The novelty of this study and its findings is the identification, disaggregation, and articulation of the novice maker experience using a behavioral lens. The behavioral approach applied here can pragmatically inform instructional design and investigations of how *making* can support learning trajectories. Ultimately, this dissertation highlights pathways for future behavioral research and better behaviorally informed design of makerspace-inspired instruction that grows computer science identities and skills.

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CHAPTER ONE: INTRODUCTION

Create. Build. Construct. Make. *Making* is a significant component of human culture, a *phylogenetically important event*[1], allowing us to flourish as a species. Consequently, making exists in many variations and is a root metaphor in many, if not all, human cultures. Perhaps unsurprisingly, educational researchers have been giving attention to particular forms of making in popular culture—commonly referred to as *making* and the *maker movement*, which often occur in *makerspaces*. Making has been asserted to positively influence students' learning in many ways. In the study presented here, the researcher examines the behavioral interactions of novices engaging in making activities and how such interactions align to support computer science (CS) identity and skill trajectories.

Namely, this study was motivated by the multi-faceted need to broaden CS participation. Currently, there is a shortage of CS graduates from US universities (cf. Kosheleva & Kreinovich, 2013) making it difficult to maintain US global competitiveness and to fulfill the increasingly diverse demands of the domestic market (Tornatzky, Macias, & Jones, 2002). Moreover, CS participation is not representative of greater demographic trends in the US (Dowd, Malcom, & Macias, 2010; NSF, 2011). Despite attempts to facilitate increased student participation in the CS workforce, many groups remain significantly underrepresented (e.g., Hug & Thiry, 2011) including women and members of non-white and non-Asian demographics (Falkenheim & Hale, 2015). This underrepresentation appears in many forms arising from a history of varied sociocultural factors negatively impacting diversity in CS (e.g., Rasmussen & Håpnes, 1991).

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[1] As per William Baum in Conversation May 2016, cf. Baum (2012)

Purpose of the Study

A better understanding of sociocultural factors that impact CS-related skill and identity trajectories is needed to facilitate more diverse matriculation, achievement, and persistence in CS. Such improved understandings could benefit groups currently underrepresented in university CS programs (e.g., Barker & Garvin-Doxas, 2004) and improve CS practices through greater diversity (e.g., Everett & Watkins, 2008). As such, the study presented here has sought to behaviorally identify and analyze interactions that contribute to or impede the development of generalizable CS identity and skill trajectories, especially maker identities and their constituent CS identity and skill behaviors.

Further, this study attempted to behaviorally analyze novice interactions occurring at the intersections of making, CS, identity, and skills while seeking to identify the salience of environmental and social factors, including physicality and the influence of relational frames. This study is intended to support instructional designers and educators in adopting those elements of makerspace activities that are most beneficial in supporting *maker* and CS identity and skill trajectories. Also, this study is one of few behaviorally articulated studies that investigate novice CS learning and the makerspace experience (cf. Davis & Mason, 2016), which illuminates pathways for the behavioral investigation of makerspace and CS education trajectories for researchers and instructional design.

Research Questions

The overarching questions that guide this study are: 1) What are the discernable factors influencing behaviors of novice makers from underrepresented demographic groups during introductory CS activities at a makerspace? 2) What are the characteristics of those behaviors?

More specifically, in order to gain traction on these overarching questions, the researcher sought to identify:

- What personal history and related effects does the researcher discern in participants' verbal behavior[2]?
    - Which relational frames, especially those referencing self and identity[3], can be discerned among the participants' verbal accounts?
- Which are the social and environmental characteristics of makerspace-situated verbal behaviors, their antecedents, and their consequences for novice CS students?
    - At what frequency are antecedents social, environmental or a combination thereof?
    - What types of verbal behavior, mands, intraverbals, tacts, or echoics, are emitted by participants?
    - With what frequency are the consequences of verbal behavior, social, physical, or some combination thereof?
    - What are observable relations among environmental characteristics, such as the modality of stimuli and operants, and rate of participants' makerspace behaviors?
- What are the discernable relations among participants' verbal behavior, relational frames, and makerspace participation?

Overview of the Methodology

This study builds on the behavioral phenomenological methodology, commonly referred to as the *Reno methodology*, which represents a more event-based, qualitative approach to

[2] i.e., what prior conditioning, including relational frames and concomitant derived relational responding can be discriminated by the researcher?
[3] i.e., deictic frames

functional behavior analysis (e.g. Leigland, 1989, 1996, McCorkle, 1978, 1991). In short, behavioral phenomenology can be described as an in situ functional analysis of behavior, such as learning to code at a makerspace, made possible by the observer's prior discrimination training, rather than relying on experimental manipulation of the environment. Although behavioral phenomenology was developed by one of radical 'behaviorism's more prominent scholars, Willard Day (1977), and his students, it is unfamiliar to many practicing behaviorists. Consequently, the review of literature provides many details about behavioral phenomenology, its relation to current behaviorism, its evolution, and its affordances for research.

Definition of Terms

As the study presented here is intended for disparate audiences, it is important to clarify the use of terms as they appear in the study. The key terms for the study are:

- ***Behavioral phenomenology*** – an in situ examination of how interactions are experienced behaviorally. The focus is on behavioral functional analysis, and, in particular, identifying what precedes and follows behavior, the antecedents and consequences. This methodology is more descriptive in nature than other behavioral methodologies as the focus is on in situ responses rather than experimental manipulation.

  More than other behavioral approaches, behavioral phenomenology relies on the researcher's practice in noticing nuances of behavior, i.e., her discrimination training, to discern behavioral relationships. Also, behavioral phenomenology incorporates researcher reflexivity, whereby researchers discuss discriminated behavioral phenomena with other behavior analysts (Day, 1977; Lahren, 1978; Mascolo, 1986; McCorkle, 1978).

- ***Control*** – the increased or decreased likelihood of a given response in the presence of a stimulus (cf. Skinner, 1953b). Typically, responses are influenced by multiple variables; this is described as *convergent multiple control* (Michael, Palmer, & Sundberg, 2011, p. 4). *Divergent multiple control* indicates the increased likelihood of multiple responses in the presence of a particular stimulus (ibid).
- ***Derived relational responding*** – closely related to the phenomenon of language, derived relational responding refers to a process whereby responses are influenced by the resultant relations implied by two or more other relations. There are many types, or ‘classes’, of derived relational responding.

  One type of derived relational responding is the process of *combinatorial entailment*. For example, if a student is trained that *a* blocks are placed before *b* blocks and that *b* blocks are placed before *c* blocks, then given *a* and *c* blocks, the student will place *a* blocks before *c* blocks (S. C. Hayes, Fox, et al., 2001, p. 30).

  Regardless of relation type, such derived relational responding is arbitrarily applicable to any trained relation, and, as such, dependent on contextual clues (S. C. Hayes, Fox, et al., 2001, p. 25).
- ***Embodied cognition*** – the premise that behavior, including complex verbal behavior, such as cognition and problem-solving, can be grounded in an organism’s physical interactions with the environment and not need to be processed by an internal voice (Chemero, 2009c).
- ***Functional analysis*** – a process to identify lawful relations — reoccurring, definable relationships, among various factors, especially environmental

antecedents and consequences, influencing the frequency of behavior. Functional analyses are often differentiated from *functional behavioral assessments* on the basis of experimental control (Mayer, Sulzer-Azaroff, & Wallace, 2014b, p. 181); however, functional analyses may be descriptive rather than experimental (Day, 1977; Leigland, 1996).

The functional analyses used here may also be described as ‘Leiglandian’ or preliminary functional analyses (cf. Groden, 1989).

- ***Functional consequence*** – the reinforcing effects of behavior such as escape from aversive antecedents or positive social reinforcement (Mayer et al., 2014b, p. 181).
- ***Generalization*** – indicates that the control, or influence, of a particular stimulus is shown across multiple contexts. For example, a student will exhibit an increased frequency of prosocial behaviors at school as well as at home in the presence of an adult.
- ***Identity*** – identities are articulated as implicit and explicit identification with patterns of behavior used to define a class, which can also be described as molar behaviors existing in a frame of coordination (similarity) with the self (cf. Stewart, 2013). For example, if someone exhibits patterns of behavior identifiable as the distinguishing patterns of behaviors for a larger group such as runners, chefs, or college professors.

  Having an identity signifies that one’s articulated self is in one or more relational frames, such as coordination or distinction, to one or more culturally identifiable behavioral repertoires. Identities can then affect responses and responsiveness to environmental factors. Identities are considered to function as motivating operations, that is, they may influence susceptibility to reinforcement through identity-derived relations. Also, identities can serve as "superordinate signals" (meta-discriminative stimuli), similar to rules, that influence how people behave (Rachlin, 2014, p. 180).

- ***Maker*** –"maker" connotes familiarity with the broader maker movement, a cultural trend of sharing, developing, and discussing projects in electronics forums, at Maker Faires, and at makerspaces (Halverson & Sheridan, 2014). The term maker commonly describes identity and related behaviors occurring with the construction of creative projects in informal contexts, often with craft elements, hobbyist electronics, and embedded programming.
- ***Makerspace*** – a third[4] space where makers gather to work on independent craft projects. Often such locations and organizations offer trainings and hold collaborative construction events (Martinez & Stager, 2013; cf. Sheridan et al., 2014).
- ***Mentalism*** – the attribution of behavior to non-observable internal causes. Mentalisms are considered problematic in many branches of psychology (cf. Chemero & Silberstein, 2008), as mentalisms are often functionally equivalent to mysticism (S. C. Hayes & Brownstein, 1986; Leigland, 1989; L. L. Mason, Davis, & Andrews, 2016; Moore, 1981).
- ***Molar behavior*** – a pattern of behaviors related to an overarching trend occurring over time. Such molar behaviors can be contrasted with discrete or molecular

[4] A location outside of school and work where people commonly socialize, such as churches, clubs, and other organizations (Bhabha, 2012).

behaviors that are situated in the moment. For example, *being a chef* is a molar behavior that is comprised of molecular behaviors, such as making a soufflé, that occur repeatedly over time (Baum, 2002).

- ***Radical embodied behaviorism*** – the intersection of radical behaviorism and radical embodied cognition focused on disaggregating modalities of behavioral interactions, with subsequent emphasis on identifying relationships among physically grounded environmental variables and arbitrarily applicable derived relational responding (cf. Chemero, 2009c).
- ***Relational frame*** – A relational frame is "a specific class of arbitrarily applicable relational responding" dependent on context that is both a *process* and an *outcome* (S. C. Hayes, Fox, et al., 2001, p. 33). Value-altering effects, the likelihood of attending to and being reinforced by various events, are considered outcomes (S. C. Hayes, Fox, et al., 2001, p. 33). The increased strength of control exerted by the completion of making project by someone responding in a frame of coordination with makers is the outcome, which then increases the likely emission of more teleological patterns of maker behavior, including a maker identity or self.

  The process is the forming of "relational operants", which can be articulated as "becoming a maker" (S. C. Hayes, Fox, et al., 2001, p. 34). As an example, a student creates a technology product, such as a programmable watering bowl, one consequence is "becoming a maker"[5] or "being a maker,"

[5] Interchangeable with unconditioned reinforcers such as receiving a cookie and conditioned reinforcers such as praise.

which owing to the frame of coordination with makers can serve as a conditioned reinforcer.

- ***Self*** – a relational frame that functions as content, process, and context (Stewart, 2013). Namely, a deictic, or self-referential, relational frame whereby individuals differentiate themselves from others. Most especially, self may refer to an individual's report of covert verbal behaviors, that is, a "private world" (Stewart, 2013, p. 272).

Organization of the Dissertation

Chapter One, this chapter, provides the rationale for broadening CS participation through the maker initiative and the rationale for behaviorally investigating such efforts. The purpose of the study and its guiding research questions are elaborated, key terms are explained, and this description of the dissertation's organization concludes the chapter.

Chapter Two gives an overview of the empirical and theoretical literature underpinning this study. First, a history of CS-related interventions is provided, transitioning into an exploration of embodied cognition and its posited and measured effects. Then, the chapter focuses on defining identity, operationalizing identity, and the effects of identity. Next, a brief unifying discussion of makerspaces and their relationship to CS, embodied cognition, and identity is provided. Lastly, the behavioral underpinnings for the study are discussed and justified. The behavioral articulation of CS and maker identity and skill trajectories, the significance of relational frames are provided. In particular, the epistemological and methodological affordances of radical behaviorism, behavioral phenomenology, relational frame theory, and embodied cognition are elaborated.

Chapter Three outlines the methodology. A description of the setting and participants is followed by a report of the materials and timeline used in the makercamp intervention. Next, the data collection process is detailed. Only a brief discussion of data analyses and visualizations are provided as Chapters Four and Five provide greater specifics about the analyses and representation particular to the interview and makercamp components. A lengthier treatment of the role of the researcher in behavioral phenomenology is then accompanied by a short rationalization for the addendum of inter-rater reliability measures to the behavioral phenomenological approach. The disparate inter-observer agreement measures are more fully discussed at the ends of their respective chapters. Lastly, the connections among the research questions, data, and analyses are clarified.

Chapter Four provides analyses of the data gathered during the pre-, between-, and post-camp interviews. The chapter begins by outlining the importance of the interviews and their analyses. The methods of analysis and visualization specific to the interviews are clarified. Next, interview data are organized by participant and interview. Each interview is illustrated with diagrams of participants' self-articulated relationships to CS and making-related issues, prior interactional histories, and discriminated sources of control. The limitations of the interview analyses are accompanied by an examination of inter-rater reliability for the interview analyses. Lastly, overarching trends are summarized to clarify the selection of participants for extreme case analysis in Chapter Five.

Chapter Five presents the 'extreme case' analyses of two participants' verbal behaviors during the makercamp (Onwuegbuzie & Leech, 2007). First, the importance of the data and their interpretation to the research questions is discussed. Next, the selection of the extreme cases for closer analysis is explained. Then, the methods of data analysis and visualization used in the chapter are introduced. Findings are organized by antecedents, then verbal behavior type, contingencies, and patterns among them—particularly in relation to individual participants. Caveats to the classification, analysis, and interpretation of verbal behaviors, their antecedents, and consequences are noted. Lastly, patterns across antecedents, verbal behaviors, and their contingencies are examined.

Chapter Six concludes the dissertation by synthesizing findings from Chapters Four and Five. The resulting summation ties together the disparate data and their relationships to answering overarching and component-specific research questions. Building on the synthesis of findings, the researcher elaborates on implications for behaviorally informed instructional design of makerspace-grounded introductory activities, especially CS activities. The dissertation then concludes with recommendations for future behavioral phenomenological studies, especially those examining novice participation in CS and maker communities.

CHAPTER TWO: REVIEW OF THE LITERATURE

In order to better contextualize the usefulness of examining makerspaces and maker-activities as pathways to increasing CS participation, it is first necessary to review problems of CS underrepresentation, the approaches that have been taken to bolster CS participation, and how "making" initiatives relate to efforts to increase CS participation. The following chapter first reviews CS interventions for broadening participation, which are broadly discussed in relation to social and physical characteristics. The review then examines two compelling conceptual frameworks for examining CS learning trajectories—embodied cognition and identity.

Makerspaces are subsequently introduced as a compelling context for integrating embodied cognition and identity to support CS learning. Next, the affordances and necessity of examining makerspace-CS interventions through a radical behavioral lens are articulated. In particular, problems with mentalistic approaches to identity and engagement are discussed. Moreover, the particular relevance of relational frame theory (e.g. S. C. Hayes, Fox, et al., 2001) to examining CS identity and skill trajectories is explained. The chapter concludes by explaining behavioral phenomenology and detailing how a behavioral phenomenological approach is extremely well-suited for initial behavioral investigations into maker-initiatives as pathways to increasing CS participation, especially for student demographics underrepresented in CS.

The Problem: The Need for Greater Demographic Participation in CS

The demographic distribution of students and professionals within science, technology, engineering, and math (STEM) fields has many problematic implications (NSF, 2011). Namely, STEM careers are frequently indicated to be among the most fiscally and cognitively rewarding professions (Tornatzky et al., 2002). In such terms, chronic underrepresentation of frequently marginalized demographic groups, such as women and certain ethnic minorities, raises questions of systemic inequality and dictates that efforts should be made to increase representation in the interest of social justice (Margolis, Goode, Holme, & Nao, 2008). Additionally, the underrepresentation of various demographic groups in STEM fields impedes responsiveness to consumer demands (Everett & Watkins, 2008; Margolis & Fisher, 2003b) and limits US competitiveness on the global market (Tornatzky et al., 2002). Thus, there are many reasons to improve participation by underrepresented groups. Unsurprisingly, there have been many CS-oriented interventions that have met with greater and lesser success (Beheshti et al., 2008; Guzdial, 2007).

Contextualizing CS Interventions

In discussing underrepresentation in CS, it should be noted that there is no clear consensus regarding its causes. There are, however, a few recurrent themes within the literature of CS education and STEM underrepresentation. Two trends that emerge are the roles of familiarity and aversion in influencing CS participation. researchers and practitioners have suggested interventions to bolster CS participation that can be further categorized as interventions to increase social affinity, minimize social aversion, leverage physical familiarity, and minimize physical aversion (namely, to the programming environment).

Addressing Social Factors

There are many socially grounded frameworks for broadening CS participation. Commonly, these interventions build on existing behaviors and seek to counteract aversive perceptions of CS and increase students' perceptions of self as programmer or potential programmers.

Increasing CS relevance. Many educators are attempting to increase CS interest by suing activities that incorporate social and physical elements already familiar to students (cf., Eisenberg, 2003; Goode, 2008). This scaffolding, or behavioral "chaining," of CS interest to familiar settings is intended to boost the perceived relevance of CS for underrepresented students. Many of these interventions target younger students as researchers have noted that it is familiarity accrued during childhood that holds the greatest promise for promoting later CS interest (Margolis et al., 2008).

Moreover, educators strive to provide demographically similar participants and role models so as to bolster students' perception of self as similar to programmers (cf. Greenberg & Mastro, 2008). This includes creative coding camps specifically for girls (Adams, 2007), interventions aimed at female students from socioeconomically challenged groups (Marcu et al., 2010) and from underrepresented ethnicities (Tiku, 2014; Wolber, Abelson, & Friedman, 2015), and other interventions aimed at supporting students from diverse social backgrounds (e.g., B. J. DiSalvo et al., 2009; Rich, Perry, & Guzdial, 2004; Wolz, Stone, Pulimood, & Pearson, 2010)

CS and conflicting identities. One recurrent theme in the literature examining underrepresentation in CS is the *aversive nerd* factor (Davis, Yuen, & Berland, 2014a). Namely, many researchers have indicated that CS participation is impeded by underrepresented students' (especially females') aversive reactions to the stereotype threat of CS students as nerdy, asocial, white males (e.g. Cheryan, Plaut, Davies, & Steele, 2009; Margolis & Fisher, 2003b).

In the aversive nerd relation, researchers note that problematic characteristics of nerds, such as social awkwardness, including hierarchy building, boasting, repetitive narrow interests (See Barker & Garvin-Doxas, 2004), become much more salient to the underrepresented students and deters interest in CS (e.g., Margolis & Fisher, 2003a; Rasmussen & Håpnes, 1991; Teague & Roe, 2009). Owing to the strong relation between CS and nerds, underrepresented students then respond to CS as they would to nerds—consequently avoiding CS participation (Cheryan et al., 2009).

A second social theme researchers have emphasized is students' *lack of familiarity* and *lack of perceived relevance* as the most substantive impediment to diverse CS participation (e.g. Goode, 2008; Margolis et al., 2008). For example, researchers such as Roli Varma (2007) have indicated that aversion to "nerds" may be more typical for middle-class white women at an elite university. For many minorities, the nerd stereotype is unfamiliar or a nonissue. Rather, interest in CS is impeded by a lack of familiarity with CS or conflicting obligations (Varma, 2007). Consequently, for such students, CS participation could be increased by better familiarizing students with CS career opportunities and emphasizing the relevance of CS to students' lives (e.g., Varma, 2006).

Physical Accommodations

One approach to improve CS interest has been the use of friendly drag-and-drop graphical programming environments (Maloney, Peppler, Kafai, Resnick, & Rusk, 2008; Wolz et al., 2010). although such interventions have generated positive effect among participants, students' perception of self in regard to CS often remains unchanged (Gates et al., 2011). Moreover, students, especially those with interest in CS, may respond aversively to such environments (B. DiSalvo, 2014).

There is a long history of researchers examining the relationship of physicality to novice CS trajectories (e.g. Seymour Papert, 1980; Perlman, 1976). For example, Papert (1980, p. 63), the progenitor of the LOGO programming language, describes how students' *body syntonic knowledge* can support programming and other learning. Body syntonic knowledge refers to the scaffolding (chaining) of conceptual understandings on the basis of analogies grounded in an individual's physical experiences with the world (Yuen et al., 2015). For example, students can act out the concept of plate tectonics before they can verbally articulate the concept (Singer, Radinsky, & Goldman, 2008)

Similarly, in recent investigations specifically examining the affordances of embodied cognition to support CS learning, researchers have noted that direct embodiment increased learners' engagement with CS activities and conceptual proficiency (Fadjo, Lu, & Black, 2009; Petrick, Berland, & Martin, 2011; C. Smith, Berland, & Benton, 2012). Researchers found that when students acted out the programs they were writing, that is, by taking an egocentric, or first person, point of view, students could better solve programming-related tasks (Fadjo et al., 2009; C. Smith et al., 2012). Smith et al. (2012) note that *collaboration* in embodied environments can support students' transition from a first person, egocentric perspective to the allocentric perspective, namely, describing elements in relationship to other elements, whereby the ability to switch between perspectives is important for concept mastery (Ackermann, 1996 as cited in Smith et al., 2012). Perhaps, even more telling of the affordances of embodied cognition, Fadjo et al. (2009) explicitly compared the effects of students' direct embodiment and *imagined embodiment* on learning CS concepts. Bolstering similar findings in previous research (e.g., Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004), Fadjo et al. found that students fared better with actual direct embodiment rather than imagined embodiment and that actual direct embodiment provided an important scaffold, specifically "an index for the affordances of each proposition" (p. 4045) to more abstract and imagination-based approaches.

Tangible Programming Environments

In the planning of CS learning environments, it is perhaps unsurprising that attention quickly turned to the programming environment and how users create programs. Perhaps owing to unfamiliar appearance and terse syntax, researchers soon identified that “typical” programming interfaces could impede students’ engagement with CS material. Shortly after the advent of LOGO, Perlman (1976) soon found that traditional interfaces, i.e., typing, impeded children’s learning of programming concepts (as described by McNerney, 2004, p. 327). Perlman consequently developed various tangible interfaces with cards (the slot machine) and a button box to allow students to better program robot turtles; however, such interfaces and the accompanying turtles proved too unreliable and too expensive for schools (McNerney, 2004, p. 328).

It is unsurprising then that approaches to tangible programming and programming-like environments have evolved over time (McNerney, 2004). Throughout this evolution, there have been many toylike approaches that support advanced programming, including using LEGO (e.g., Lawhead et al., 2002) and LEGO-like construction kits (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008) that allow the programming of physical artifacts such as robots. Alternatively, in other environments, learners assemble physical blocks to program virtual objects as with AlgoBlocks (Suzuki & Kato, 1995) and physical objects as with Cricket (McNerney, 2004). However, certain aspects of physicality and learning have not been examined through a behavioral lens, such as whether and how task topography as a precursor or consequence to verbal behavior may better support learners (cf. Abrahamson, Trninic, Gutiérrez, Huth, & Lee, 2011; Chemero, 2009a).

In the evaluation of tangible programming environments, few findings are presented other than the common observations that students find the environments engaging, that the environments piqued students’ interest, and that students were able to quickly make use of the environments. (For a list of tangible programming interfaces reviewed for this study, please see

Appendix C1.) This paucity of evidence is observed by Horn et al. (2009) who note "minimal evidence" for the efficacy of tangible programming interfaces (p. 3). This dearth of empirically significant findings has also been observed regarding the broader literature of tangible interfaces (Marshall, 2007; Zaman, Vanden Abeele, Markopoulos, & Marshall, 2012). (For an extended discussion of tangible interfaces, see Shaer and Hornecker, 2010.)

As discussed earlier, educational researchers, such as Seymour Papert and his protégés (Blikstein, 2013; Eisenberg, 2003; Seymour Papert, 1980) have long advocated incorporating programming into the physical world and the physical world into programming projects. It is here, at this intersection of CS learning and *embodiedness* research, which examines how an individual's history of physical interactions with the world inform understanding (Fischer, 2012), that questions of causality may become unavoidable (cf. Berland, 2008). Namely, questions arise whether tangible interfaces and other physically situated programming practices are effective because "cognition" begins with the body or because such approaches build on recognizable cultural forms that are commonly physical (cf. Horn, 2013).

Mike Horn, comparing the affordances of graphical and tangible programming (Horn, 2006; Horn & Jacob, 2007; Horn et al., 2009), suggests that differing experiences with interfaces more likely arise more from familiarity with implicit cultural associations of the physical (tangible) interfaces than from hardwired genetic predisposition (personal communication, June 23, 2014). If such an assertion were true, then the salience of *familiarity* would supersede *physicality* (cf. Horn, 2013) in computer science instructional design considerations. However, given the extant granularity of investigation into tangible interfaces and physically situated computing, the differences, such as strength of control, are not readily discernible.

Embodied Cognition

There is reason to suspect that physically situated activities building on students' embodied cognition may offer more promising pathways to bolstering students' engagement, skills acquisition, and even identity development in regard to CS (e.g. Fadjo et al., 2009; Petrick et al., 2011).

Incorporating physicality and embodiedness has been found to support students in CS problem-solving (e.g., Fadjo, 2012; C. P. Smith, Berland, & Martin, 2013). Also, physically situated, tangible programming environments can facilitate longer programming engagement for students (Horn et al., 2009). Almost since the inception of programming initiatives for students, educators have argued for greater physicality in student programming environments (e.g., Perlman, 1976). It comes then perhaps as little surprise that in seeking to broaden CS interest and participation, researchers have frequently emphasized the importance of establishing connections between physical materials familiar to students, such as buttons and fabric, and programming (e.g., Eisenberg, 2003).

Embodied cognition refers to the notion that humankind's intelligence is rooted in its corporeality (Anderson, 2003a). It is an ontological and epistemological position emphasizing that humankind's interactions—including intelligence, thought, consciousness, and learning—with the world are significantly shaped and informed by its physicality (Barsalou, 2008; Wilson, 2002). For educational researchers, there is significant motivation to understand how embodied cognition can be leveraged to support learning (Lakoff & Johnson, 1999; Lakoff & Núñez, 2000).

Within embodied cognition research, there are currently two large camps with adherents spread between them (cf. Barsalou, 1999): the representationalists[6] and the non-representationalists (Chemero, 2009b). Similar to behaviorists, nonrepresentational embodied cognition researchers, also called *radical embodied cognitivists*, reject any reliance on non-observable symbolic manipulations and emphasize how such approaches impede scientific discovery (Chemero & Silberstein, 2008). This similarity arises in that both the behaviorist and radical embodied cognitivist positions are grounded in pragmatic principles of parsimony, particularly, that it is more reasonable to analyze observable events rather than to suppose complex internal processes and structures (Baum, 2005; Chemero, 2009b).

Researchers are increasingly identifying affordances of embodied cognition for supporting the mastery of cognitively complex content (Núñez, Edwards, & Matos, 1999; Singer et al., 2008; C. Smith, 2012). However, the majority of discussions examining embodied cognition are overwhelmingly theoretical. Moreover, there are no readily identifiable reviews or syntheses of empirically grounded data explicitly examining the affordances of embodied cognition.

Discernible Quantitative Effects

Increased physicality seems to almost consistently promote stronger effects with perhaps a few notable exceptions (Jansen, Dragicevic, & Fekete, 2013; Manches, O'Malley, & Benford, 2010). By and large, students were positively benefited in problem-solving tasks using embodied cognition (Antle, Droumeva, & Corness, 2008; Esteves, van den Hoven, & Oakley, 2013; Manches et al., 2010). Similarly, students' understanding of concepts and learning of new concepts commonly benefited from physical grounding (Cress, Fischer, Moeller, Sauter, &

[6] By definition, representationalists are mentalists.

Nuerk, 2010; Han & Black, 2011; Malinverni, Silva, & Parés, 2012; Vitale, Swart, & Black, 2014). These quantified benefits align strongly with more qualitatively described embodied cognition affordances described below (e.g. Abrahamson & Trninic, 2011; Berland, Martin, Benton, & Petrick, 2011; Fadjo et al., 2009; Howison, Trninic, Reinholz, & Abrahamson, 2011).

Rather than simply discussing engagement as a goal unto itself, it is important to consider how engagement is defined or observed and to consider its relationship to learning in tangible environments. Perhaps, a key to understanding the importance of embodied cognition and the benefits of environments that leverage embodiment is understanding the role of physical iteration on conceptual habituation, what might be described as familiarization through *fussing* (cf. T. Martin, 2009b). As mentioned briefly in the proceeding quantitative meta-analysis, environments relying on physicality seem to promote more frequent and extended interaction, that is, more iterations (Cuendet, Jermann, & Dillenbourg, 2012; Schönborn, Bivall, & Tibell, 2011; Vitale et al., 2014). This observed engagement[7] relates significantly to the potential learning affordances of embodied cognition.

For example, Howison et al. (2011) indicate that students' frequent physical iterations with the mathematical imagery trainer led to proficiency in verbally articulating rules, whereby physical mastery preceded verbal articulation. As such, this finding highlights not only the potential primacy of physically grounded understandings (Kirsh, 1995; Seitz, 2000; Singer et al., 2008), but underscores the role of iterative approximation to developing conceptual mastery (e.g., T. Martin, 2008). For example, researchers have found that students' iterations and tinkering when developing computer programs serve distinct functions, such as the development of new code and refinement of existing code (Berland, Martin, Benton, Petrick Smith, & Davis,

[7] Frequency and length of iterations is a more objective operationalization of engagement as it does not presuppose any internal states.

2013). Similarly, in examining the learning of mathematics with tangibles, Martin notes that students' *fussing*, that is, their purposeful and exploratory approximating iterations, supports their solving of mathematical problems and development of mathematical skill through "serendipitous variability" (T. Martin, 2009b). Such examinations of iteration in problem-solving spotlight strong relationships among physically distributed learning (T. Martin, 2009a) and epistemic actions, actions for problem solving purposes (Kirsh & Maglio, 1994). Moreover, such findings bolster the case for eschewing discussions of internal causes and highlight the importance of physicality in discussions of cognition.

Embodied Cognition and Computer Science

Researchers have taken varied approaches to examining the effects and potential affordances of embodied cognition and other physicality for supporting computer science learning. The discussion presented in this dissertation focuses on the learner's physicality and not the physicality of the environment to be programmed. This is an important distinction as focusing solely on the physicality of the environment rather than learner physicality would be overly broad and nonproductive including far ranging topics such as educational robotics, which often does not explicitly articulate connections to embodied cognition (cf. Berland, 2008; Yuen et al., 2015).

Identity

Identity can substantively influence students' engagement with academic content and the pursuit of related careers (Johnson, Brown, Carlone, & Cuevas, 2011). Specifically, students' identities have been identified as influencing participation with CS (Hewner & Knobelsdorf, 2008). Similarly, *perceived possible selves,* the selves that an individual can perceive for themselves, can influence engagement and participation in many activities (Markus & Nurius, 1986). Moreover, perceived possible selves are important because if a student does not perceive that they can be an academic, if they discern that people like them do not engage in academics, their participation may be impeded or they may respond aversively to academics (e.g., Cuero & Kaylor, 2010; Fordham & Ogbu, 1986).

It then becomes increasingly problematic that middle school students' predictions of having STEM careers relate more significantly to later careers than do test scores (Tai, Liu, Maltese, & Fan, 2006). This achievement of perceived possible STEM careers is the inverse corollary of not pursuing careers perceived as out of reach (cf. Markus & Nurius, 1986). As such, possible selves can provide a necessary perceived relationship between a predicted future self and STEM careers that can influence and increase students' engagement with academic content (e.g., Lee & Hoadley, 2007). Moreover, the less the perceived discrepancy, that is, the greater the perceived shared similarities, the more likely a student will perceive an identity as possible (Hoffner & Buchanan, 2005; Klimmt, Hefner, Vorderer, Roth, & Blake, 2010; McDonald & Kim, 2001). it is unsurprising that CS education researchers have noted the need to expand students' perceptions of who pursues CS careers (Hewner & Knobelsdorf, 2008) while providing appropriate, namely, relatable, peer role models (Beheshti et al., 2008).

Defining Identity

There is no single agreed upon definition for identity (cf. DeVane, 2014), but there are some commonalities across disparate discussions of identity (Mead, 1934; Phelps, 2015). One such common theme is the notion that individuals represent the locus of intersection for a myriad of identities that can be expressed at any moment (DeVane, 2014). Behaviorally, *being the locus of a myriad of identities* signifies that a person's behaviors are informed by a plethora of behavioral repertoires and molar behaviors of persona and identity. Identity can be described as an individual's perception of self in interaction with and separate from others (cf. Stewart, 2013).

When considering the importance of identity, it is important to bear in mind that there are many aspects of students' identities and many factors that impact students' multiple identities (e.g., Norton & Toohey, 2011). For example, learners' identities depend on their perceived roles in society and in their families, which in turn impacts perceptions of educational relevance (Wilkins & Kuperminc, 2010; Zambrana & Zoppi, 2002). Additionally, students' relationships to their own and other cultures, including feeling unwelcomed, can impact their academic identities and academic success (e.g., Schwieter, 2011). That is, a students' sense of validation greatly influences academic performance (e.g., Duff, 2002) and having academic identities validated can support academic growth even more than targeted skill development (cf. Hertzberg, 1998).

Many Articulations of Identities

Noting that identities impact academic performance and may facilitate CS interest is a bit of a glittering generality without having operationally defined identity. In light of the many disparate descriptions of identity, it is helpful to note that identity is typically discussed as *developmental* or *interactionist* (DeVane, 2014, p. 222). Similar to notions of Piagetian cognitive development, the developmental approach to identity posits phases or levels of identity occurring as part of an epigenetic process (Erikson, 1968; Marcia, 1966). By contrast, the interactional approach to identity emphasizes the contextual and molecular nature of identity dependent on and influenced by social interaction (Gumperz & Cook-Gumperz, 1982; Ochs, 1993).

The most glaring differences between the two approaches are variability and time. A developmental approach considers identity to be a product in flux that is only discernible over time, whereas an interactional approach to identity emphasizes the situatedness of identity expression and the interactional histories contributing to potentials for “identity performance” and “identity work” (e.g., Snow & McAdam, 2000). In synthesizing many approaches to identity, DeVane (2014) indicates the necessity of pressing analytic boundaries of the two identity camps and considering identity at different scales: traversing developmental scales (i.e. molar) and interactional scales (i.e. molecular).

Making, Makers, and Makerspaces

Makerspaces represent a confluence of potentially beneficial social and physical factors that may positively support CS engagement. Positive social effects may support the development of maker and CS identities, whereby maker identities may also support longitudinal CS interests (Davis & Mason, 2016). Similarly, physical aspects of a learning environment, including iteration and physical modality, may also support short and long-term participation.

Interwoven with the social affordances of makerspace participation, is the development of maker identities, which represents a promising approach to broadening CS participation by groups currently underrepresented in CS (cf. Sipitakiat, Blikstein, & Cavallo, 2004). The literature is replete with examples of successful STEM identity trajectories nourished in childhoods rich with making and tinkering. Massimo Banzi (2009), one of the key developers of the Arduino microcontroller, recalls a childhood spent tinkering and exploring electronics by deconstructing and rebuilding toys and other found items. Similarly, Andre diSessa (2001), the physicist and educational researcher, explains that much of his understanding of physics was rooted in early tinkering with household electronics.

Moreover, making has significantly shaped scientific success stories for individuals not commonly associated with the maker movement. A stark example of an uncelebrated tinkering trajectory is B.F. Skinner, one of the most recognized founders of radical behaviorism, who was an avid childhood tinkerer (Skinner, 1985). Skinner's tinkering is a compelling example as he was a lifelong maker whose making later translated directly to discoveries in the science of behavior. Foremost, his discovery of schedules of reinforcement was made possible by his making; namely, the graphs that rendered schedules of reinforcement more observable were discovered through the process of tinkering with the lever press equipment that then generated logarithmic graphs (Skinner, 1979). Indeed, Skinner found making to be so essential to the understanding of behavior that he required that many of his students manufacture operant conditioning chambers in order to better understand the principles of behavior (Skinner, 1979).

The Push for Making

It is then perhaps unsurprising that increasing attention is being given to the phenomenon of making and makerspaces in modern culture and educational research (See Vossoughi & Bevan, 2014). Researchers are highlighting the promise of a class of activities commonly referred to as making—activities whereby participants create objects, many of which incorporate technology, necessitate CS skills, and are shared in public forums. For example, students might program microcontrollers to light up LEDs in specific patterns on hand-made clothing items.

Currently, educators and *make* advocates are extolling the pedagogical affordances of making, including greater engagement with and concomitant learning of technologically complex production processes (e.g., Blikstein, 2013). Researchers highlight that students engage more readily, more intently, and in a more authentically interdisciplinary manner with make projects than classroom practice (e.g. L. Martin, Dixon, & Hagood, 2014; Vossoughi & Bevan, 2014).

The Special Maker–CS Connections

Efforts to promote CS interest and making are closely connected. For example, *constructionists*, who were among the first and most vociferous to promote the unique educational affordances of computers and programming (e.g. Seymour Papert, 1980; Seymour Papert & Harel, 1991), have begun investigating the how makerspaces and making may support student learning and lifelong learning trajectories, especially, with regards to how maker activities might increase CS interest (e.g., Blikstein, 2013; Martinez & Stager, 2013; Stager, 2013a).

Although investigations of makerspaces are relatively new, substantive attention has been given to discussing the social-learning affordances of makerspaces (e.g., Brahms, 2014). Researchers have indicated that makerspaces exemplify situated learning, whereby novices learn in active participation with more experienced others and are encouraged through social interaction (cf. Vossoughi & Bevan, 2014). Similarly, makerspaces have served as focal points to connect families in creative endeavors (Brahms, 2014) and bring students' "everyday lives" to make-projects while providing authentic, relevant connections to CS (e.g. Barton, Tan, & Greenberg, 2016; Blikstein, 2013).

Generalizability of Maker Knowledge and Habits

Perhaps more promising than the variety of discrete skill development, such as programming and fabrication skills, observed in makerspaces, researchers have identified that making necessitates *adaptive expertise*, that is, the "resourcefulness" required for identifying novel solutions (L. Martin et al., 2014, p. 1). Such adaptive expertise refers to the processes, skills, and previous training that facilitate students' application of domain specific knowledge to broader contexts, for example, adapting CS skills to personally relevant programming projects such as programming a chicken feeder. Exercising adaptive expertise requires that multiple frames of reference be brought into coordination (L. Martin et al., 2014, p. 7).

Such adaptive or generalizable expertise has many behavioral parallels to the identity behaviors (cf. Phelps, 2015; Roche & Barnes, 1997; Stewart, 2013) that support multifaceted interest in STEM (cf. Sheridan et al., 2014; Vossoughi & Bevan, 2014, p. 13). Specifically, some researchers have noted that makerspaces provide the kinds of interest-driven and personally relevant roles most likely to foster emergent STEM problem-solver identities. Namely, maker projects provide opportunities to connect STEM learning to students' existing interests in a longitudinal and self-directed manner (Vossoughi & Bevan, 2014, p. 11). For example, researchers have observed that experienced makers integrate makerspace-developed behaviors broadly across all facets of their lives (L. Martin & Dixon, 2013, p. 3).

Maker and CS Progressions

Beyond generally knowing that some maker novices become CS-maker experts, in order to train or shape the progression from novice to expert, it is important to have a closer analysis of the progression and its constituent tasks (cf. Crandall, Klein, & Hoffman, 2006; Kirschner, Sweller, & Clark, 2006). Beginning such analyses, Dixon and Martin have disaggregated clusters of identifiable behaviors corresponding to the progression of participation in making and maker identities (2104). Dixon and Martin have found that maker behaviors progress from *exploration* (random testing) to *exchange* (purposefully seeking out others, asking and refining questions) to *deliberate engagement* (including specific, individually initiated, longitudinal projects) (Dixon & Martin, 2014, p. 1591). this progression resembles the progression of novice programmer behaviors identified through learning analytic examination of code edits; novice programmers progress from exploratory to more refined (goal-driven) tasks to very specific (debugging) behaviors (Berland et al., 2013). Broadly speaking, such a progression, from general behaviors to more specific, nuanced behaviors is characteristic of becoming an expert (Latour, 2004); this progression is behaviorally referred to as discrimination training (cf. Hanson, 1959). Accordingly, it is not the question of whether maker-specific behaviors, such as identity and behavioral repertoires, develop, but how the development of such behaviors is facilitated, particularly for novices and across contexts.

In short, there is appreciable potential in makerspaces and makerspace-informed activities for improving CS engagement. the development of maker identities, the concomitant reinforcement and strengthening of adaptive problem-solving behaviors, and the generalization of such behaviors in a “life-wide” manner could substantively bolster CS participation and interest, especially among underrepresented groups (cf. Dixon & Martin, 2014).

Examining the literature of makerspaces, significant attention is given to social aspects such as situatedness, learning as part of a community, and social reinforcement. Students, makers, and researchers acknowledge the importance of a maker-oriented community and emphasize its potential for supporting the development of maker skills and identities (e.g., Brahms, 2014; L. Martin & Dixon, 2013). However, there is also concern that makerspaces and makerspace-informed activities may not be supporting or even accessible to those who would most benefit from such initiatives (Buechley, 2013; Halverson & Sheridan, 2014). Consequently, it behooves researchers to clearly identify, in measurable terms, those elements of makerspaces and make-informed activities most effective in supporting maker identities and concomitant CS engagement for underrepresented populations (Halverson & Sheridan, 2014, p. 9).

Clarifying Questions for Novice Maker Identity

Makerspace advocates have indicated that makerspaces and related maker activities may support diverse maker identities and increased engagement with CS. The increased engagement is, often attributed, in part, to the social situatedness, that is, the shared aspect of maker projects, and to the modality of the activities. The specifics of who is supported and how support occurs remain to be clarified. Most especially, there is a pressing need to examine whether and how novices, especially those from demographics underrepresented in CS, are supported or discouraged in their initial interactions with makerspace activities.

Making: Embodiment Grounded in the Familiar

The makerspace environment provides a context simultaneously facilitating increased physicality and familiarity. Approaches to programming within makerspace and related contexts highlight and exemplify the blurry line separating physicality and familiarity as such approaches build on literature advocating real world, physically situated programming projects.

For example, Eisenberg (2003), in recasting Papert (1980), highlights that in order to scaffold, i.e., iteratively shape, children's programming knowledge, programming should begin with physically familiar objects and materials such as dolls, fabrics, buttons, and other everyday items (cf. Buechley, Hendrix, & Eisenberg, 2009). Indeed, building on the physical world to incorporate and even necessitate programming projects is a common theme in maker and broader constructionist literature. In discussing the democratization of programming and technology, researchers (Sipitakiat & Blikstein, 2010a, 2010b; Sipitakiat et al., 2004) emphasize the usefulness of building, or "grounding," programming projects on physically familiar (i.e., relevant) contexts such as chicken coops and crop water monitors.

Makerspaces and programming share close connections (cf. Stager, 2014)**.** Among the common, explicit goals for makers is the incorporation of programming concepts and skills into personally relevant projects. This trend of programming for physically grounded relevance is evident in the many embedded programming projects requiring microcontrollers and minicomputers such as the Arduino (Banzi, 2009; Vaughn, 2012), GoGo board (Sipitakiat et al., 2004), and Raspberry Pi (Upton & Halfacree, 2012) to interact with the physical world. Make advocates such as Buechley (Buechley, Eisenberg, Catchen, & Crockett, 2008; Buechley & Hill, 2010), Kafai, and Fields (Kafai et al., 2013, 2014; Kafai, Fields, & Searle, 2012) indicate that physically situated projects, for example, programmable clothing, provide the needed medium to engage underrepresented populations with programming.

Summary of Empirical Research

The overarching trends of physical and social stimuli influencing CS and makerspace engagement can be seen to manifest themselves as identity and embodied cognition. Given the nebulous and controversial nature of identity and embodied cognition and their social and physical natures, which could be considered irreconcilably distinct (cf. Latour, 2004), an appropriately pragmatic approach is needed to examine the two elements intersect in a makerspace to influence novice maker participation with introductory CS activities.

Radical Behaviorism

If researchers and educators are to leverage identity to support CS participation and engagement, then they must operationalize identity in measurable and actionable terms. Such an endeavor to operationalize identity may attract criticism, as concepts with a strong cultural history, such as identity, are commonly romanticized and mythologized, and consequently are burdened by conceptual root metaphors that may impede scientific analysis (S. C. Hayes, Hayes,

& Reese, 1988; Pepper, 1942). In particular, core cultural metaphors such as self and identity become increasingly likely to attract explanatory fictions (cf. Michael, 1993b). Namely, explanations for behaviors are frequently circular, and, subsequently, leave little room for scientific, i.e., behavioral, intervention (Moore, 2003). As Dymond and Barnes (1997) note:

> The behavioral view therefore differs from many non-behavioral accounts, in that … [behaviors are] attributed to a specifiable history of reinforcement and not to an ill-defined mentalistic realm in which the concept of self is somehow miraculously embedded. (p. 191)

The need to behaviorally discuss identity and interest trajectories (cf. Gee, 2000) can be illustrated by considering the problems presented by nonempirical, mentalistic approaches to identity. A pop-cultural example, the television series *Herman's Head* (1991), premised on showing the interactions occurring inside the head of the protagonist Herman, highlights the problems of common cultural metaphors for identity. In the show, the facets of Herman's personality, including manifestations of machismo, feminism, paranoia, jealousy, and intellect, were each personified by different actors.

The problems with such a conceptualization of identity become quickly apparent. Individual persona cannot exist within the confines of one's head and interact with one another as people do. Moreover, this presents a problem of recursion, similar to the *mind as a homunculus* problem[8]. If a personality or identity is a conglomeration of other identities (personae), then such identities would, in turn, be conglomerates of subpersonae interacting with one another ad infinitum (See Figures 1 and 2), a proposition that is more obfuscating than clarifying (cf. Skinner, 1964, p. 80, 1974e, p. 130). The casual reader may dismiss such a cultural

[8] Namely, if the mind is articulated as a presence that processes external information for an individual, then the question remains as to how information is processed for the mind. As such, a recursive chain of homunculi is created rather than insight as to how the individual interacts with world.

reference as merely a metaphor found in entertainment (cf. Docter & Carmen, 2015); however, the homunculi metaphor extends beyond the scope of casual entertainment.

Figure 1. The mind as recursive homunculi. This figure illustrates the paradox of mediated behavior, if human behavior is mediated by an internal voice, than each internal voice may just as likely be mediated by a mediated voice much like a homunculus (a little person).

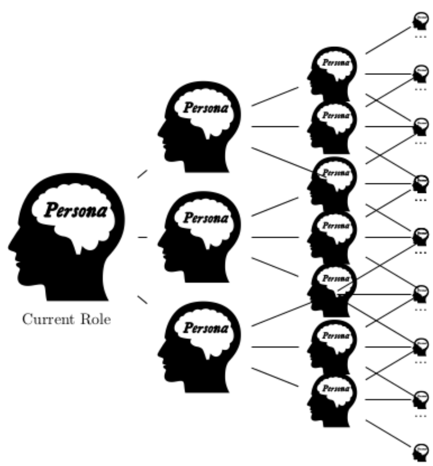

Figure 2. Recursive composition of personalities. This figure illustrates the similar paradox, if human actions are controlled by distinct personality elements, than such elements may also be subdivided ad infinitum.

A great deal has been written regarding conflicting and myriad personalities and identities that constitute individuals (e.g., Squire, DeVane, & Durga, 2008). Such discussions of personalities may be very entertaining and may even represent useful epistemological shorthand for discussing identity-related phenomena (cf. S. C. Hayes & Brownstein, 1986); nevertheless, such approaches to identity are limited in many ways. The greatest limitation is that such approaches are not pragmatic—positing multiple personalities within an individual is ill-suited to measuring or altering identity-related behaviors. Rather than imagining an internal world of the mind, the educational researcher is better served by first focusing on measurable and observable identity-related behaviors and interactions (Skinner, 1974d; Stewart, 2013).

Moreover, a pragmatic approach is necessary, because mentalistic explanations for identity reify educational disparity by placing the onus for learning on ineffable characteristics of individuals, which results in victim blaming for systemic inequalities, such as underrepresentation in CS (cf. Ahl, 2006; Moore, 2003). Namely, if the causes for behavior, including participation in CS, lie in nebulously defined personal characteristics, such as a myriad of posited identities, then the responsibility for change is removed, or at least substantively shifted, from educators and researchers, and, quite problematically, placed upon students.

Further, when discussing the relations among CS identity, skills, makerspaces, and embodied cognition, educators and instructional designers are better served if such relations can be discussed in a more nuanced manner, such as articulating the weights of various factors, rather than in binary terms. Using relational frame theory (RFT) concepts such as *combinatorial entailment* and *derived relational responding* (D. Barnes-Holmes, Hayes, & Dymond, 2001; S. C. Hayes, Barnes-Holmes, & Roche, 2001) as well as articulating sources of multiple control (Michael et al., 2011) may provide such necessary nuance.

Externalizing Identity: A Pragmatic Focus

Considering the limitations of mentalistic, nominal descriptors, questions arise as to whether and how identity might be meaningfully operationalized so that it might be identified, measured, and, eventually, purposefully shaped. Further, the operationalization of identity calls into question how factors supporting or impeding identity and identity-related behaviors may be usefully identified and disaggregated.

Rather than discussing identity as the expression of several identities or personalities within one person, it is more pragmatic to indicate that an individual's behaviors are influenced by the individual's current situation, their past experiences, and the behavior itself (Skinner, 1974c, p. 163). Identities or personalities can then be considered behavioral repertoires related to the context in which they arise (Skinner, 1974c, p. 164). For example, a student might identify as a "school boy" or a "prankster" and behave accordingly within a school context, for example, being disruptive, but the student may display contrasting behaviors outside of school, such as, helping with housework (cf. Cuero & Kaylor, 2010).

Discussing *behavioral repertoires* rather than the internal or mental interaction of personalities may seem a trivial distinction or semantic quibbling—it is not. Discussing an individual's behavioral repertoires shifts attention from imperceptible phantasma to discussions of learners' interactions with the environment and the characteristics of that environment (Michael, 1993b; Moore, 2003). Focusing on observable events then moves the onus of participation and engagement from posited internal factors, such as modal personalities, to more tractable and measurable environmental factors that might support or impede the expression of behaviors and behavioral repertoires.

Observing and Enacting Identities: Identity as a Molar Behavior

A description of identities and personae as simply *behavioral repertoires* may seem insufficient—and rightly so. In common culture, when people discuss maker or *gamer* identities, they are referring to larger patterns of behavior over time and not simply context dependent behaviors. For example, a maker identity entails more than using wood glue to fix a loose handle. A maker may attend local makerspaces, discuss making with others, attend Maker Faires, develop longitudinal projects, and share project progress on online forums.

Such long-term patterns of behavior can be described as molar behaviors (Baum, 2011a). Molar behaviors are aggregate patterns of behavior over time, for example, being a caring partner, which consists of many discrete, potentially repeated behaviors, such as buying presents, asking about the partner's day, and being affectionate, exhibited over time. Here, *identity* and *persona* refer to *explicit* and *implicit identity* and are delineated on the basis of self-differentiation. Identity is used to denote a self-referential discrimination of a molar behavior, for example, a student identifies as a maker. Whereas *persona* denotes the molar behavior and concomitant behavioral repertoires, for example, the student attends makerspaces and tinkers with the Arduino. Additionally, as discussed later, the molecular behaviors compromising the molar behaviors of an identity or persona can be described as a class of behaviors in that the molecular behaviors may serve similar, or *equivalent*, functions (Sidman, 2000, 2009).

As an example, the term *maker project* does not describe one particular activity, but rather may refer to a large number of possible activities with a large number of interchangeable potential constituent components. Similarly, molar maker (or CS) identities or persona may be constituted of many differing, frequently overlapping, and frequently similar constituent molecular behaviors.

Having shifted the description of identities to observable patterns of behavior, a discussion of factors influencing molar behaviors, such as identities and persona, and their constituent molecular components becomes more tractable. Moreover, the empirical approach to identity used in this study was implemented to afford a more tractable approach to discussing the factors that may influence the expression of identities and the interaction among such factors.

As noted earlier, identities were operationalized as molar behaviors in order to facilitate the observation and measurement of maker and CS identity and skill behaviors. By shifting attention from posited internal personae to molar behaviors and constituent molecular behaviors, the discussion of maker and CS identity then emphasizes observable empirical phenomena. Such a shift is, however, only a first step, as the underlying goal of such an investigation is the identification of discrete factors contributing to the establishment, strength, transferability, and evocation of molar behaviors and interactions among such leading to molar behaviors recognizable as CS, maker, and other STEM identities.

Current Paradigmatic Constraints

Attribution of CS success and interest to internal factors such as “intrinsic motivation” is problematic as is positing internal factors as determinants of makerspace participation. Frameworks that promote the acceptance of nominal explanations and unobservable internal factors, whether they are real or explanatory fictions, are unreliable and more likely to impede the understanding and management of behavior than promote it (Baum, 2011b; Skinner, 1977). Therefore, an approach is needed that challenges those persistent cultural narratives that reify the marginalization of underserved students in CS (Moore, 2003). Also, investigating and articulating the affordances of embodied cognition for supporting maker and concomitant CS skills and identity trajectories may prove advantageous given the strong alignment between embodied cognition and behavioral perspectives. As such, the interdisciplinary lens formed at the intersection of the science of behavior (Skinner, 1953a) and radical embodied cognitive science (Chemero, 2009c) formed the epistemological underpinnings of this study.

The slow ascension of embodied approaches to robotics serves as an important example and as a potentially important precedent. The behavioral approach to robotics using reflexive and associative learning was almost completely disregarded for many years in favor of the more intricate, less tractable approaches that relied on elaborately defined, internalized, world models (Brooks, 1996). Now however, embodied (Anderson, 2003a) and dynamic, nonrepresentational (Beer, 2000) approaches to robotics and probabilistic approaches to parsing natural language (e.g., Caraballo & Charniak, 1999; Charniak, 2000) have supplanted other less productive, less tractable approaches to machine learning in CS and human learning research (Anderson, Richardson, & Chemero, 2012; Chemero & Silberstein, 2008). In summation, CS research and its understanding of cognition was impeded by failing to appropriately consider the role of environmental, contextual responsiveness in cognition and by failing to take a parsimonious approach to articulating how "intelligence" interacts with the environment (Chemero, 2009b). Similarly, current attributions of interest in or success with CS to inner structures, such as "the geek gene," are equally problematic and to be avoided (Lister, 2011).

CS: Meritocracy, Identity, and Confronting Dominant Cultural Narratives

Another related example attributing CS success to internal, unobservable factors in computer science classrooms and the profession is the common myth of meritocracy, namely, that success and recognition in CS most significantly relates to skill achieved through hard work owing to "intrinsic motivation." This belief is commonly traced back to "hacker" culture (Levy, 2001; Rasmussen & Håpnes, 1991). Drawing upon such myths of meritocracy, there is frequent posturing in CS classrooms, which is uncorrelated with ability (See Teague & Roe, 2008), that disproportionately alienates those students most frequently underrepresented in computer science majors and careers (Barker & Garvin-Doxas, 2004; Margolis & Fisher, 2003b; Teague & Roe, 2009). The myth of meritocracy in CS has far-reaching consequences. For many CS educators, merit that arises from intrinsic motivation and ability, not the responsibility of instructors, is considered the primary determinant for pursuing a CS major and concomitant CS careers. The origins of such "motivation" and ability often go unquestioned, frequently leaving the role of the environment, identity, and cultural expectations (including stereotypy) unquestioned (cf. Barker & Garvin-Doxas, 2004; Hewner & Knobelsdorf, 2008).

In order to challenge the status quo and alleviate underrepresentation, it is necessary to confront such unquestioned mentalistic assumptions. This need highlights the particular saliency of a behavioral investigation into the affordances of makerspaces for supporting nascent maker and CS identities. Similarly, if the affordances of embodied cognition, including any effects on identity or skills, are to be made meaningful to CS educators and inform their practice, then results must be presented in a manner understood by and acceptable to such educators (Guzdial, 2012). Moreover, if a transition is to occur, such as that from "Good Old Fashioned Artificial Intelligence" (GOFAI) to more behavior-based and probabilistic models, then CS educators need clearer, more easily disaggregated empirical, experimental data and analyses, that justify the importance of embodied cognition and identity to future CS success i.e., in terms that CS educators can "make sense of" (cf. Seymour Papert, 1997). A behavioral–phenomenological investigation, such as the one presented here, provides inroads to the collection and analysis of such data.

A behavioral approach is needed to confront preconceptions. There are still many members of the CS profession, educators included, who believe that merit and intrinsic factors are the determinants of CS success. For example, at the Special Interest Group on Computer Science Education (SIGCSE) 2014 conference, an invited speaker from the well-known organization Code.org, noted to a room of educators that CS was a meritocracy and was received with applause. The assertion was emphatically and adroitly rebutted by Dr. Jane Margolis, but the implication remained clear—efforts to bolster participation in CS by underrepresented students should actively work to counter problematic cultural narratives (cf. Ewick & Silbey, 1995). Namely, narratives of intrinsic motivation and self-determination, which are commonly used to justify societal inequities in CS and elsewhere, problematically attribute lack of success to internal factors (Ahl, 2006; Brookfield, 2005). Consequently, it is necessary to ground a study of CS and related maker identities in an epistemology, such as radical embodied behaviorism, that challenges such problematic assumptions. A radical embodied behaviorist approach can be used to identify molar behaviors, but also divide such behaviors into constituent components and discuss their effects and potential control.

A Case for Radical Embodied Behaviorism

The approach presented here is not without precedent. There are historical antecedents highlighting the benefits of approaching CS learning through behavioral and embodied cognitive perspectives (e.g., behavioral robotics, Brooks, 1996). Though there may be some misinterpretation, misinformation, and misrepresentation of radical behaviorism within educational research (MacCorquodale, 1970; Todd & Morris, 1983a), behavior analytic approaches have a strong track record of providing insight into otherwise intractable problems (e.g., Drash & Tudor, 2004). The strong and unique alignment of radical embodied cognitive science and behaviorist perspectives have benefited this investigation of how to better support maker and CS identity and skill trajectories for underrepresented students.

Relational Frames: Complex Relations among Complex Behaviors

RFT is one component of the science of behavior that is particularly useful for discussing the many factors influencing complex behaviors, such as identity. In particular, RFT provides a behaviorally grounded explanation for derived relational responding (S. C. Hayes, Blackledge, & Barnes-Holmes, 2001, p. 18). Specifically, relational responding refers to a person's ability to respond to arbitrarily defined stimuli and classes of stimuli (cf., Sidman, 2009; Zentall, Galizio, & Critchfield, 2002).

For example, given the characteristic *age*, if a person is told that Bill is older than Sue and that Sue is older than Sally, then through a process of combinatorial entailment, a person could verbally identify that Bill is the oldest. Stimuli may exhibit many relations with regard to one another. The most commonly identifiable relational frames include, but are not limited to: coordination, opposition, distinction, comparison, hierarchy, and deictic (See Y. Barnes-Holmes, Hayes, Barnes-Holmes, & Roche, 2002; and Appendix C2 for definitions of these relational frames).

Moreover and quite important to consider when seeking to influence behavior, relational responding is arbitrarily applicable, meaning that relational responses can be trained for any discernable characteristic of a situation, including socially defined elements (S. C. Hayes, Fox, et al., 2001, p. 25). Additionally, the influence of a particular relation on behavior depends on the interaction, that is, the competing control of other existing behaviors and relations.

RFT and Identity

As there are many competing and field-specific descriptions of identity (cf. DeVane, 2012), the behavioral perspective has been selected to provide a tractable approach to discussing identity. Specifically, the behavioral approach notes that self-awareness can be considered the behavior of discriminating one's self from the environment, a skill which has been shaped through (the contingencies of) social reinforcement (Skinner, 1974a). Moreover, self-awareness as a complex behavior is clarified as a relational frame (Dymond & Barnes, 1997). Namely, in keeping with previous work on the self (cf. Stewart, 2013), in this study, identity is articulated as implicit and explicit self-awareness, whereby identities provide rules and relations that influence behavior. Subsequently, identity related effects are predicted as a result of relational responses to physical and social aspects of the environment (cf., Y. Barnes-Holmes et al., 2002; Baum, 2002; Frankel & Rachlin, 2010).

Control

In the science of behavior, control refers to the influence that stimuli have on behavior (Skinner, 1953b). Control can be exerted by physical and social stimuli of different types. In education, control is predominantly exerted by verbal behavior (Vargas, 2013b, p. 251). Stimuli that are in the environment as well as those not present can exert control (S. C. Hayes, 1989).

Social Control

More than just being influenced by verbal behavior, the presence of others and a person's relationship to those others can influence behavior. Consider the following experience taken from educational research: when in conversation with researchers or during observation, students expressed preference educationally "preferred" activities such as problem-solving and creative endeavors, which suggests the effect of the researchers' presence on behavior (cf. Parsons, 1974). However, in the absence of researchers or in the competing presence of peers, students engaged in more problematic activities such as pulling keys off the keyboard. Such responses can be explained using a straightforward model of control and discriminative stimuli (S^D) (cf. Michael, 1980; See Figures 3 and 4) .

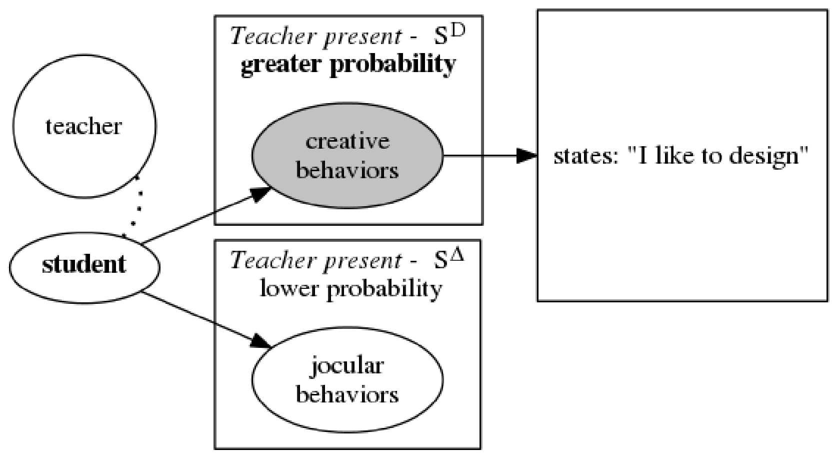

Figure 3. Teacher as signal for indicating design proclivities. This figure illustrates how the teacher signals likely reinforcement for mentioning design aspects of the game and less likelihood of reinforcement for mentioning violent aspects of the game.

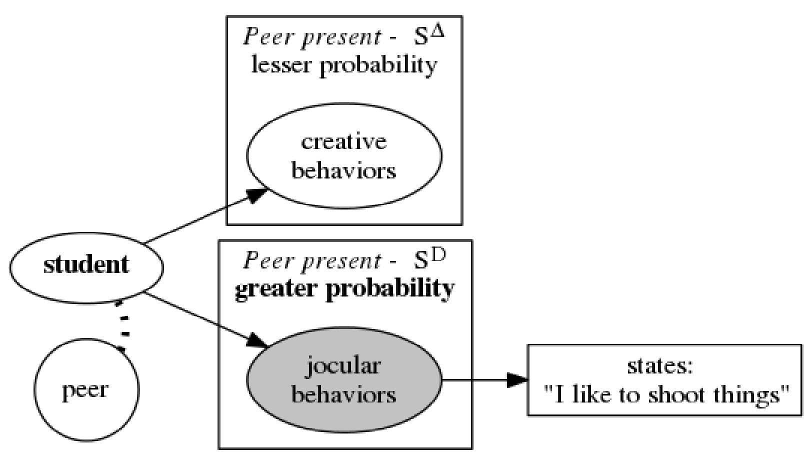

Figure 4. Peer as signal for indicating destructive proclivities. This figure illustrates how a peer signals greater likelihood of reinforcement for mentioning violent aspects of the game and less likelihood of reinforcement for mentioning creative aspects of the game.

One example from games-based learning research — during a study of students' interactions with the videogame Grand Theft Auto (GTA) (DeVane & Squire, 2008), a student indicated in the presence of researchers and without peers that he liked to use GTA to design and be creative (Figure 3). However, in the presence of a peer and researchers, the student indicated a preference for being destructive in the video game (Figures 4 and 5). The contrasting behaviors suggest competing sources of control, namely, that the peer and researchers signaling different, competing possibilities for reinforcement of behavior. The resultant behavior suggests that peer social reinforcement exerted greater strength of control on the student's behavior (Figure 5).

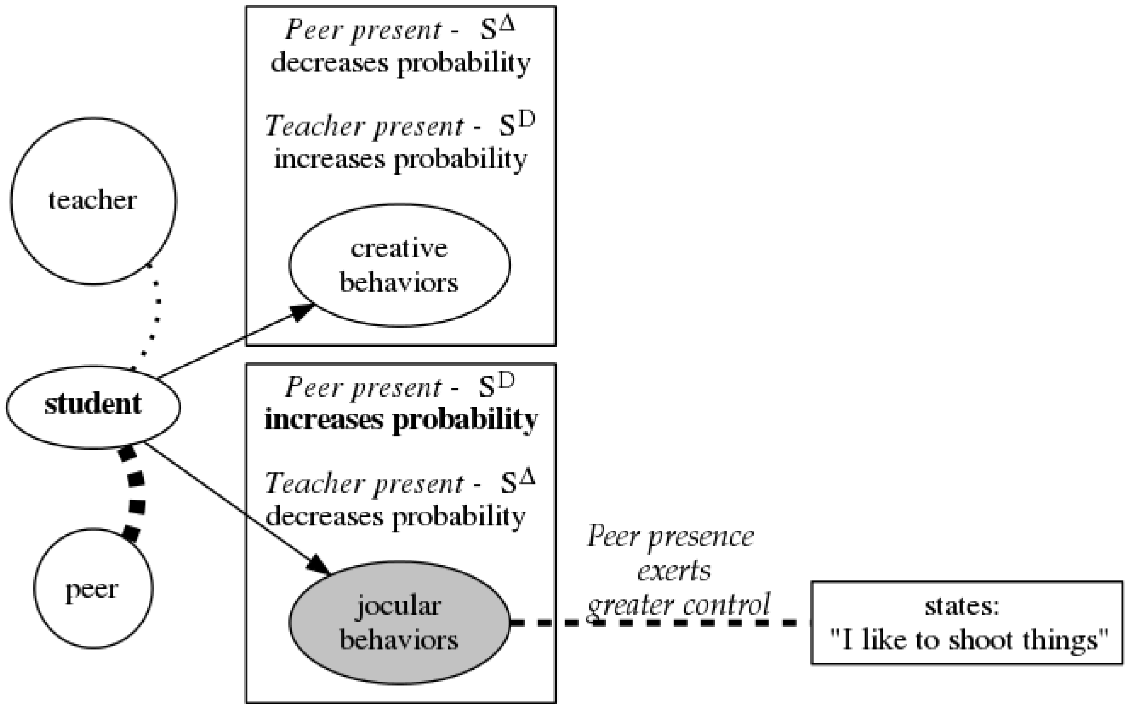

Figure 5. Multiple control of student's description of videogame-play motivators. This figure illustrates differing signals for reinforcement influencing the student's behavior.

Rule-Governed Behavior

In addition to observable social and physical stimulus control, it is important to consider the role of rule-governed behavior. Rules, which are defined by behaviorists as verbal antecedents that influence behavior (Catania, Shimoff, & Matthews, 1989), do not represent mechanistically predictable causal mechanisms. Rather, rules often exhibit only weak correlation and limited control of actual behavior. For example, a person can be told "if *x* happens then *y*" or "*y* is a member of *z*" and act accordingly. A person's actions can then be said to be under control of the rule.

Fortunately for humankind, behavior can be influenced through rules (Catania et al., 1989; S. C. Hayes, 1989). For example, a person might not eat a certain mushroom after being told, “That’s poisonous,” or not rob a liquor store having been told, “If you rob a liquor store, you will go to jail for a long time.” In neither circumstance was the person required to emit the specific behavior in order for a behavior to be trained.

Self as Relationally Framed Rules

Similarly, control can be relationally derived. For example, seeing someone engaging in behaviors commonly identified as nerdy, such as buying *Magic the Gathering* cards at a comic book store, while wearing a t-shirt depicting the TV series *Firefly,* may establish watching *Firefly* as belonging to the class of nerd behaviors. The roles of self, rules, and relations might then influence behavior. For example, if someone discriminates their *self* in a positive membership relationship to the equivalence class of nerds, the observer may choose to watch *Firefly*. By contrast, if the observer is in a non-membership or aversive relationship to nerd behaviors, that person may avoid watching *Firefly*.

Watching *Firefly* as a nerd behavior may seem a banal example (cf. Cheryan et al., 2009), but the described response relationship is also illustrative of the previously discussed aversive nerd relation to CS (See Figure 6), whereby engagement with CS is impeded or facilitated through the individual’s relation to nerd behaviors (cf. Davis, Yuen, & Berland, 2014b).

Physical Control

One need not look far to see that actions do not always correlate significantly with received or expressed verbal rules. As an example, researchers alternated the environments in which children were offered more snacks or better crayons in return for waiting, i.e., testing delayed gratification (Kidd, Palmeri, & Aslin, 2013; cf. Mischel & Mischel, 1983). In the context where the researcher was first unreliable in returning with better crayons, the children more frequently ignored verbal assurances (i.e., rules) that waiting would result in better candy and instead opted for the immediate reward. Whereas in the context where the researcher had previously returned with better crayons, the children acted according to the verbal assurance that better candy would be provided for waiting. As such, the children's behaviors were influenced to a greater extent by previous interactional histories than verbal antecedents, i.e., contingency-shaped behavior exerted stronger control than rule-governed behavior (cf. Hubert-Williams, 2014).

Motivating Operations

In this dissertation, the term *motivating operations* refers broadly to establishing operations as described by Michaels (1993a). Establishing operations refer to the increased worth of a response and its increased likelihood given specific situations, i.e., the value-altering effect that a stimulus has on the emission of behavior. There are conditioned as well as unconditioned establishing operations. An example of an unconditioned establishing operation would be the increased likelihood to eat a sandwich if hungry. A conditioned establishing operation might be the increased likelihood to discuss programming and video games upon being introduced to a CS teacher. Conversely, there are also abolishing operations. An example of an abolishing operation could be a graduation ceremony that reduces the likelihood that attendees wear flip-flops (Laraway, Snycerski, Michael, & Poling, 2003).

Physicality and Causal Connections

Examining this intersection of computer science skills, identity, embodiedness, and physicality, there are no definitive answers from computer science education researchers, constructionists, or radical behaviorists regarding the causal connections among learning, embodied cognition, physicality, and prior conditioning, i.e., personal history.

Among radical behaviorists, for some, the topography of response and stimuli (i.e., physical or verbal) is beside the point (e.g., Lahren, 1978; Patterson, 1974); for other behaviorists such as Skinner (1953a, 1957b) and McCorkle (1978, p. 61), topographies are significant, whereby physical stimuli and responses are most salient, that is, physicality is of primary importance. This primary importance and increased salience of physicality, namely, embodied cognition, is evidenced in work by researchers such as Abrahamson (Abrahamson & Trninic, 2011; Howison et al., 2011), Singer (Singer et al., 2008), and others (e.g., Antle, 2012; Kirsh, 1995), who have found that physically grounded knowledge (i.e., trained response behaviors) may precede and even supersede the control of covert and overt verbal behavior, such as rules.

Control, Physicality, and Makerspaces

The saliency of physical interactions within makerspaces and their potential role in the development of maker identity and skills suggests benefits to increased investigation (cf. L. Martin et al., 2014). Although the current literature of makerspaces shows the importance of social interaction in becoming a maker (e.g., Brahms, 2014), less explicit attention is given to the role of physicality and embodiedness in supporting the emergence of maker identities, though the ubiquity and significance of physical interaction in shaping maker skills can be discerned in the literature of makerspaces (e.g., L. Martin et al., 2014) and closely related literature of constructionism (e.g. Seymour Papert, 1980; Stager, 2014). The study presented here provides a closer behavioral examination of classes of control, namely physical and social control, and their relationships to participation in a makercamp for novice programmers. Specifically, this study seeks to identify how types of behavioral control, or influence, vary in frequency in purpose for novice makers and how such variances might relate to maker and CS identity and skill trajectories (Blikstein, 2013; L. Martin et al., 2014; Stager, 2014).

Multiple Convergent and Divergent Control of Maker Behaviors

Multiple sources of control can be evidenced simultaneously, especially for complex verbal behavior (Michael et al., 2011). The benefits posited here of participation with makerspaces and maker-informed activities draw extensively on unique affordances of the control exerted by maker identities and constituent relations, i.e., maker identity as a motivating operation (cf. Laraway et al., 2003). As an identity, maker molar behavior may be reinforced by and reinforcing of constituent molecular behaviors. This is important as maker behaviors may be generalized to a wide range of STEM-related activities including CS activities and identities.

Through the process of relational framing and derived relational responding, the exercise of maker-related skills, such as programming, sewing, and crafting, may, in turn strengthen the control of maker identity and, consequently, the saliency of related behaviors. Namely, the generalization of maker identities to varied contexts, through *arbitrarily applicable relational responding* (S. C. Hayes, Fox, et al., 2001, p. 46), can become a source of control that may compete with more immediate reinforcers and discriminative stimuli. For example, a maker identity may exert greater control over CS engagement than competing social narratives such as nerd stereotypes (See Figure 6).

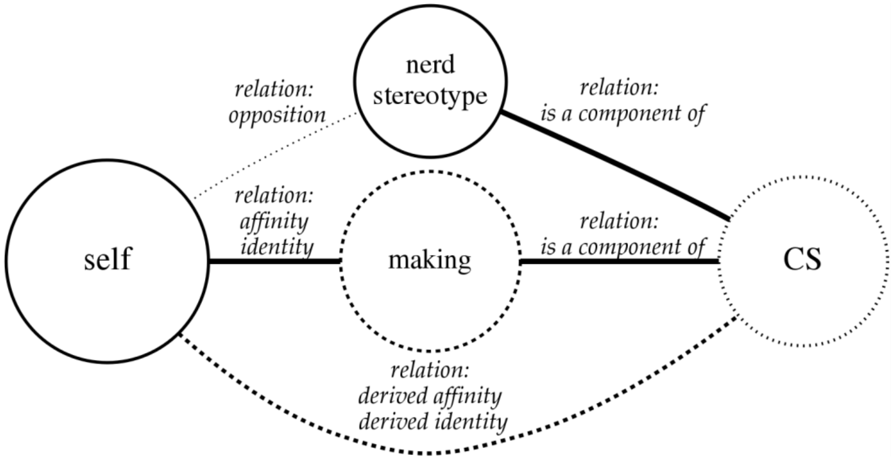

Figure 6. Simple interaction among CS-related relational frames. This figure illustrates the network of relations influencing a derived self-CS relation.

Behavioral Phenomenology and the Functional Analysis of Behavior

The lack of a functional analysis of interactions within a makerspace environment represents a deficit in many ways. The functional analysis is essentially a verbal tool of the behavior analyst for refining understandings and investigation of subject–environment interactions. The analyst seeks to determine the relationships between the subject's behavior and the surrounding contingencies (Vargas, 2013a, p. 53). Specifically, the analyst seeks to identify the consequences maintaining or extinguishing behavior (Vargas, 2013a, p. 54). This is not to say that precursors, i.e., antecedents, do not play a role in behavioral analysis.

Antecedents are discussed in functional analyses, especially of the behavioral–phenomenological kind, and may refer to immediately observable stimuli or may refer to observable or probable previous histories. For example, a response of passing the salt in response to someone saying, "Pass the salt please," relies on previous training in the English language and social behaviors (cf. Vargas, 2013a, p. 55). As such, antecedents are discussed, but in relation to and with deference given to observable consequences.

The Affordances of the Functional Analysis of Maker Behavior

The functional analysis of behavior is used to increase and decelerate the rates of target behaviors (Vargas, 2013b, p. 142). Specifically, through the inclusion or removal of identified relevant antecedents and consequences, the instructional designer can purposefully increase or decrease the likelihood of target behavior occurrence. For example, the behavior analyst as instructional designer would strive to identify and purposefully incorporate more of those elements conducive to the expression of maker identity and related skills.

The functional analysis was designed for tractable, operationalizable behavior modification and research (Leigland, 1996; Moore, 1975; Skinner, 1945). In essence, the functional analysis is an empirical survey intended to identify salient characteristics of environment–behavior interactions and their resulting influence[9] on behavior (Leigland, 1996, p. 115). Namely, the analyst should provide an observable and verifiable description of behavior–environment interactions and a functional description of such, describing the relationship between behavior and consequence (Leigland, 1996). Moreover, when discussing complex behaviors, such as abstraction, researchers are better served by observing others and identifying the visible results of those complex behaviors (cf. Skinner, 1957b, pp. 112–113 as cited in Leigland, 1996, p. 114).

Functional analyses, especially descriptive rather than experimental (Groden, 1989), rely substantively on the researcher's prior training and consequent interpretation (McCorkle, 1978). Regardless of whether descriptive or experimental, the goal of the functional analytic process remains the identification of the functional properties, i.e., observable relationships, facilitating behaviors of interest (Leigland, 1996, p. 115). The primary strength of this process is that all

[9] Stimulus control

findings may be readily “cashed out.” Namely, as all findings and relationships can be empirically observed, they can then be better acted upon, i.e., emulated or eliminated, within an educational environment (Leigland, 1996, p. 115; cf. Skinner, 1945) and used to inform the design of learning environments. Consequently, the research presented is here was posited on the supposition that given the recent positive valuation of makerspaces and makerspace-situated learning for education, that functional analyses of the interactions occurring in makerspaces and makerspace-type situations might benefit instructional designers, researchers, and educators.

A Dearth of Functional Analyses of Makers, Making, and Makerspaces

Prior to this research, there were no identifiable functional analytic investigations of interactions within makerspaces and makerspace-informed learning environments. Many factors contributed to this deficit. In part, the lack of substantive behavioral investigation may arise from the relative recency of the educational (e.g., Blikstein, 2013) and pop-cultural attention (Doctorow, 2010; Dougherty, 2008) given to such spaces. Nevertheless, many researchers have begun investigating the educational affordances of makerspaces (e.g., Brahms, 2014). However, these investigations have not been behavior analytic. This lack of behavior analytic functional analyses of makerspaces owes to a confluence of factors. Outside the field of radical behaviorism, there is substantive misunderstanding and misrepresentation of behaviorism (MacCorquodale, 1970; Todd & Morris, 1983b). Furthermore, many proponents of constructionist, hands-on, community-situated, learning who most commonly investigate makerspace environments (e.g., Stager, 2013b) consider themselves openly at odds with behaviorism (Martinez & Stager, 2013, p. 18).

Regardless of epistemological biases, a functional analytic, behavioral investigation of the maker phenomenon is meaningful, timely, and necessary for many reasons. Behavioral analytic approaches have frequently and substantively demonstrated significant benefit in improving learning and other behavioral outcomes (Mayer, Sulzer-Azaroff, & Wallace, 2014a; Miller, 2006), even with some of the most intractable problems (Drash & Tudor, 2004; Iwata, Dorsey, Slifer, Bauman, & Richman, 1982; L. L. Mason & Andrews, 2014). Also the behavioral, functional analytic investigation of novice verbal behaviors in a makerspace environment presented here should provide worthwhile recommendations for future research (Day, 1977; Lahren, 1978; Mascolo, 1986; McCorkle, 1978).

Summarizing Justification:

Behavioral Phenomenological Investigation of Novices in a Makerspace

The research examined in this review of literature highlights the timeliness of a behavioral phenomenological investigation (Day, 1977; Lahren, 1978; Mascolo, 1986; McCorkle, 1978) of novice participation in a makerspace environment. The research is exploratory in nature, as is common and appropriate with emergent fields of investigation (Hays & Singh, 2012c; Lahren, 1978). However, although exploratory, the research is intended to illuminate and better articulate several key phenomena associated with learning in makerspace environments. Broadly, this researcher intended to identify whether and when maker-related identity and skill behaviors are supported or undermined within a makerspace environment. More specifically, the researcher has sought to identify whether and how maker and related identity and skill behaviors are supported or punished through interactions within the makerspace environment. Particular attention is given to disaggregate potentially varying saliency of discriminative stimuli and reinforcer modality and dimension. In brief, the researcher has attempted to identify those elements most observably impacting and relating to maker skill and identity development, whereby modality and physical and social dimensions of the elements are emphasized.

Impetus for Behavioral Phenomenological Research

Behavioral phenomenology represents the intersection of several key trends in the field of radical behaviorism (cf. Day, 1969, 1977). Describing the underlying rationale for behavioral phenomenology, McCorkle (1978), citing Day (1976c), indicates that behavioral phenomenology should “open up the crude concept of discriminative stimulus” (p. 53). McCorkle’s (and Day’s) assessment bears substantive unpacking (provided in Chapter One); however, it should be noted that the statement and the supporting discussion found elsewhere in McCorkle’s dissertation highlight the saliency of three later refinements of behavioral knowledge: relational frame theory (Y. Barnes-Holmes et al., 2002; cf. Sidman, 2009), the concept of multiple control (Michael et al., 2011), and even embodied cognition (e.g., Chemero, 2009b).

Perhaps predicting the importance of relational frames, McCorkle (1978) draws attention to “relations as instances of contingencies” (p. 54). Namely, when developing a nuanced “analysis of antecedent stimulus control” (McCorkle, 1978, p. 52), the researcher should not merely consider the 1:1 relationship between antecedents and emitted behavior, but rather seek to contextualize them within the myriad relationships informing current behavior (D. Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000). It should be noted that the discussion of antecedents is concerned with prior operant conditioning, i.e., prior reinforcement or punishment of emitted behavior, and not a simple stimulus–response model of behavior (e.g. Skinner, 1935). Moreover, it is important for the behavioral researcher to strive to distinguish and discriminate “the important range of sub-categories” of behavioral antecedents, i.e., controlling factors, influencing behavior (Day, 1976c, p. 13 as cited by McCorkle, 1978, p53).

The Environment and Classification of Interactions

An underlying prerequisite of behavioral phenomenology is an intense focus on the description of the environment (Lahren, 1978; McCorkle, 1978). Though this focus refers broadly to verbal and nonverbal, social and nonsocial elements, it certainly suggests the appropriacy of closely examining the role of physicality in learning environments. Moreover, Day's admonishment to better disaggregate subcategories of behavioral antecedents, i.e., interactional histories, lends credence to efforts to better identify the varied effects and potential benefits of embodied cognition (Brice, 2013; Chemero, 2009a). In keeping with Leigland (1996, p. 115), preference is given to the term *interactions* rather than stimulus or response as behaviors may function as both.

It should be noted that for many radical behaviorists and embodied cognition experts (e.g., Chemero & Silberstein, 2008), the dichotomy implicated for some by the term embodied cognition, e.g., as if there are two types of cognition—"embodied" and "mental" (cf. Barsalou, 1999) is a bit of a misnomer. for behaviorists (L. J. Hayes & Fryling, 2015) and many others (e.g., Thelen, 2000), there are not two readily separable types of cognition, because all behavior occurs in one world—"the world of physics" (Skinner, 1953a, p. 139). And for a behaviorist, "Behavior is the action of the whole organism, not its parts considered separately" (L. J. Hayes & Fryling, 2015, p. 152). Consequently, at its epistemological core, the discussion here does not revolve around two varied types of cognition, but rather the saliency of various *properties* of discriminative stimuli in the "controlling environment" (Skinner, 1953a, p. 129) and in attempting to identify the relevance of various dimensions of stimuli (Skinner, 1953a, p. 133), such as physicality, tactility, and sensory-motor relations.

As discussed previously, although one can readily draw parallels and make connections across behavioral and *embodied cognition* perspectives (cf. Chemero, 2009b), such a proposition is not without caveats. As this is true with broader epistemological concerns, so too, is it true with regard to behavioral phenomenological research (Lahren, 1978; McCorkle, 1978). For example, Lahren (1978), a key behavioral phenomenological researcher, follows Patterson (1974) in not ascribing a special status to verbal or nonverbal response classes (Lahren, 1978, p. 65). Lahren justifies this indicating that the modality of responses is irrelevant as long as responses are functionally similar (Lahren, 1978, p. 65).

By contrast, McCorkle highlights the important of "objects," i.e., physicality, drawing on Skinner's (1957b, pp. 109–111) discussion of the particular salience of physical phenomena in informing humankind's understanding of the world. Namely, McCorkle and Skinner's discussion suggest that object-terms form the foundational level of human understanding. Moreover, the discussion indicates that one's ability to discriminate builds on differential reinforcement of physical properties, and that, consequently, verbal behaviors, including advanced verbal behaviors such as cognition, are grounded in the physical realm (McCorkle, 1978, p. 61 citing Skinner, 1957, pp. 109-111).

Subsequently, given the particular salience of physicality (McCorkle, 1978, p. 62) and the promise of embodied cognition for supporting complex behaviors (e.g., Anderson, 2003b), educational researchers may benefit from further investigation into the differing effects of social and physical precursors, cues, resulting behaviors, and their consequences. Therefore, this study has sought to disaggregate social and physical control and discuss those in relation to verbal behaviors, the most observable behaviors that reveal identity, relational framing, and engagement with CS and maker activities. In short, this study provides a behavioral–phenomenological examination of novice responses to an authentic makerspace during introductory CS activities, an analysis of the relationships among the social and physical aspects of the makerspace and the resulting experience, and the implications for using makerspace activities to support CS-related identity and skill trajectories.

CHAPTER THREE: METHODOLOGY

The purpose this research was to identify whether and how novice behaviors potentially salient to maker identity and skills occur within a makerspace environment. The researcher sought to identify the interactions facilitated within a makerspace environment and by common maker-type activities that may best support emergent maker and CS-related identity and skill trajectories. This research provides timely insight for makerspace research and highlights promising next steps in makerspace-grounded research and instructional design.

A behavioral–phenomenological study was conducted on participants where they were intently observed in situ while interacting in authentic makerspace activities at a local makerspace. Special attention was given to examining verbal behaviors, as verbal behaviors should provide the greatest observable insight into identity and skill trajectories (cf., Dymond & Barnes, 1997; O Hora & Barnes-Holmes, 2000; Skinner, 1984). The observation occurred during makerspace activities at a two-weekend-long *makercamp*. The makerspace activities and concomitant instruction are adapted from activities previously observed occurring naturally within a makerspace environment. The instruction was developed in coordination with the makerspace members who typically design and deliver such workshops.

Research Goals

Fundamentally, this behavioral phenomenological investigation provides an introductory functional analysis of novice behaviors occurring in a makerspace during and around engagement with common, introductory maker instructional activities. In articulating the research and findings, the researcher has sought to provide substantive description of the environment and participant responses, especially verbal behaviors, occurring within a makerspace environment. By doing so, the researcher seeks to identify promising pathways for future investigation and development of makerspace-situated and makerspace-informed instruction.

It should be noted that the goal of this study was not a longitudinal investigation of effects. Rather, the intent was to provide intense scrutiny of the behavioral interactions occurring in situ within makerspace-grounded instruction.

Participants

Six participants were recruited from the researcher's classes and school of instruction: David, Luis, Osiel, Sara, Lili, and Yessenia.[10] Students were all of high school age, older than 12 and younger than 18. Five of the six students attended non–CS classes taught by the instructor. The sixth student, Sara, was familiar with the researcher, but did not attend his classes. Additionally, she had attended a Pre-"Advanced Placement" (AP) CS course not taught by the instructor. The students represented populations commonly underrepresented in computer science and in makerspaces (cf. Buechley, 2013). Three of the six students were female and three male. Two of the three female students were Hispanic. Identification of the third female participant's ethnicity could jeopardize confidentiality. Among the male participants, one participant was Hispanic; the other two male participants were multiethnic. It should be noted that five of the six participants were members of the same magnet program. Socio-economic data were not collected.

Participant Recruitment

Participants were purposively selected from Central Texas high school students familiar with the instructor. Participants were first solicited verbally for inclusion. Then, the researcher spoke with purposively selected participants who best fulfilled target sample characteristics. The

[10] Pseudonyms

researcher noted that participation would not influence course grades. After providing initial informal, verbal consent, participants were provided with parental assent and student consent forms detailing the purposes of the study, anticipated outcomes, a description of confidentiality measures, and other participant rights and expectations including the right to withdraw at any time.

Inclusion and Exclusion Criteria

Students from demographics underrepresented in CS were given preference in recruitment. For example, Latina students were specifically invited to participate, as only 2% of computer science majors are Latina (NSF, 2011). Similarly, younger students, such as ninth graders, not currently enrolled in a computer science class were given preference. Given the study's focus on qualitative data collection including approximately a projected twenty hours of video observation and four hours of interviews, analysis, and discussion, the initial goal was to focus on three participants. to bolster against effects of potential attrition, six participants were included. As such, only one participant attended each session and only three participants attended both weekends.

Other Makerspace Attendees

In addition to selected research participants, the makercamp was attended by other attendees. This inclusion of general members of the public was a purposeful design decision. As much makerspace literature highlights (e.g., Brahms, 2014), the makerspace experience is expected to evidence traits of community-based learning. Consequently, in keeping with the naturalistic goals of this phenomenological study, participation of non-study participants was solicited from the broader maker community. As such, the makercamp was advertised through usual makerspace channels including the makerspace's social media, including Facebook, Twitter, and a listserv, as well as those of cooperating organizations such as a local nonprofit, community-based art organization, and a local university's New Media program. Additional attendees were allowed to participate free of charge, but were required to sign audio and video release statements. Also, minors were allowed to attend with signed parental release forms.

Setting

The makercamp was held on two consecutive weekends at a makerspace in a large, predominantly Hispanic, central Texas city. The makerspace is located close to downtown in a diverse, not affluent neighborhood. The space itself contains three large rooms: the large meeting room with industrial shelves with tools, such as self-constructed 3-D printers, a large laser cutter, a ham radio, multiple workbenches, and other miscellaneous technology and spare parts. The second adjacent room is more garage-like in appearance with a mill, a lathe, a drill-press, automotive-style tool boxes, a table saw, an acetylene torch, an arc welder, and other large tools. The third room contained the "classroom" where the makercamp occurred. Approximately six tables were organized with four Raspberry Pi computers and monitors per table. Given the Raspberry Pis and connected equipment such as breadboards, there were often many cables on the floor and across the tables.

Materials and Intervention

Makerspace Attendance

Students were observed during a two-weekend-long maker course at the local area makerspace. In addition to the six participants, the workshops were attended by current makerspace members, members of the makerspace's extended social network, and local area students. Seventeen participants registered initially. Participation fluctuated daily. Approximately twenty participants attended the first workshop and approximately ten participants were in attendance for the last workshop. The workshop was offered on both Saturday and Sunday of two consecutive weekends. The workshop was scheduled for approximately 4.5 hours each day from 11:00 a.m. to 3:30 p.m. (See Appendix A1 for a more detailed makercamp timeline.)

Materials

In order to attract members of the maker community in addition to participants recruited for the study, the makercamp was promoted as a "gentle introduction to making with the Raspberry Pi" (See Appendix C3). The focus on the Raspberry Pi (RPi) and related materials was influenced by several factors. Within the maker community, there is noted interest in the Raspberry Pi because it is a credit card–sized computer that can directly interface with electronics components (e.g., Upton & Halfacree, 2012). Additionally, GNU/Linux operating systems (OSes) and beginner-friendly programming libraries, including Scratch and Python, make the RPi an affordable and accessible introductory programming platform for beginners (cf. Parham et al., 2014).

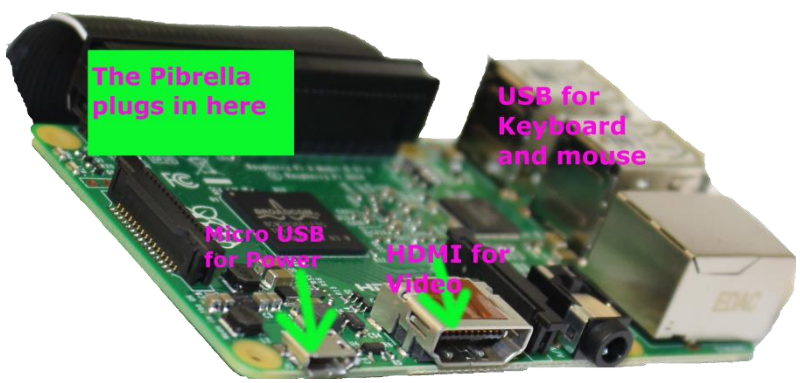

Figure 7. The Raspberry Pi as labeled for makercamp. This figure is an image used at the makercamp to illustrate the parts of a Raspberry Pi.

Learner progression with the Raspberry Pi and programming was scaffolded at both hardware and software levels. During week one, at the hardware level, participants began programming with the PiBrella (See Figure 8). The PiBrella provides integrated electronics components, such as LEDs, buttons, Piezos, and motor controllers, to facilitate quicker access and ability to programmatically interact with hardware, so that knowledge and of circuits and electronics is not a prerequisite.

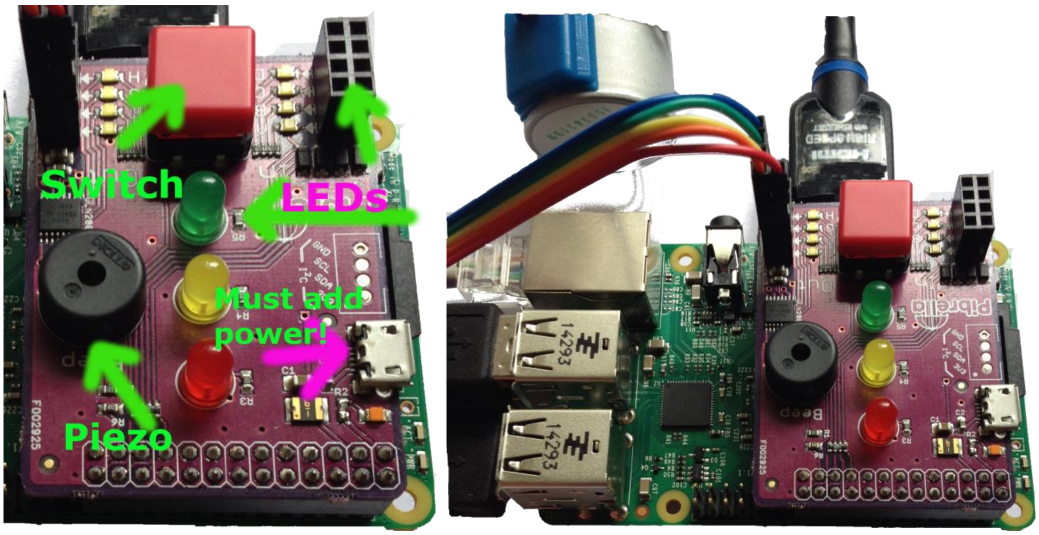

Figure 8. Pibrella. This figure illustrates the PiBrella add-on for RPi as illustrated for the makercamp (left) and the PiBrella connected to a Raspberry Pi and Stepper-Motor (right).

Then, in the second weekend of camp, participants began to use less structured, more open-ended components such as the PiCobbler that connects the Pi to breadboards and breadboards that are then connected to discrete electronics components such as LEDs, Piezos, and resistors (See Figure 9).

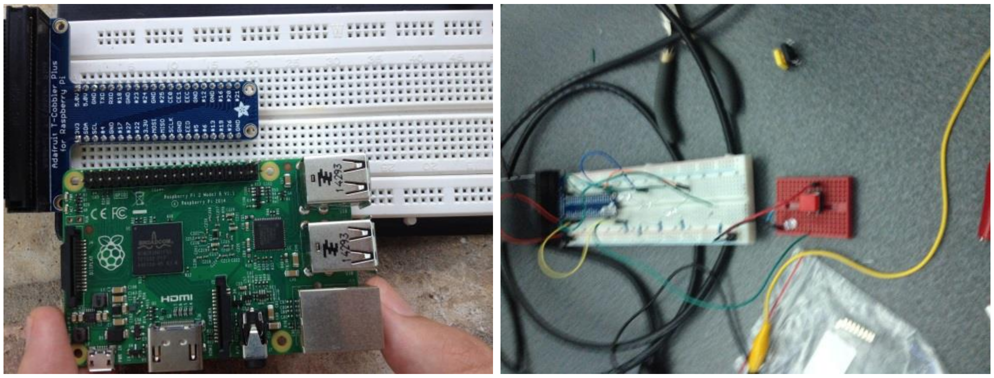

Figure 9. PiCobbler connecting RPi and breadboard. This picture shows a PiCobbler connecting a Raspberry Pi to a breadboard.

Similarly, week one of the makercamp began by using the drag-and-drop software language Scratch (cf. Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010) that provides what is commonly described as a *low-entry* or *intuitive* programming environment. Makercamp participants used the Scratch general purpose input-output (GPIO) library to program the RPi and interact with add-on components such as the PiBrella (See Figure 8). During week two, on the last day of the makercamp, participants transitioned to using the Python programming language, an interpreted, text-based language topographically similar to other professional programming languages (See Figure 10).

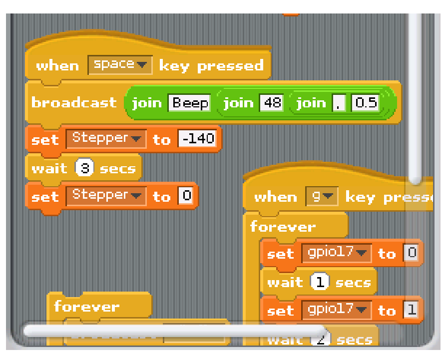

Figure 10. A code example from Scratch GPIO. This picture illustrates the drag-and-drop programming environment Scratch using the GPIO library.

```
import RPi.GPIO as GPIO ## Import GPIO Library
import time ## Import 'time' library.  Allows us to use 'sleep'

GPIO.setmode(GPIO.BOARD) ## Use BOARD pin numbering
GPIO.setup(7, GPIO.OUT) ## Setup GPIO pin 7 to OUT

## Define function named Blink()
def Blink(numTimes, speed):
    for i in range(0,numTimes): ## Run loop numTimes
        print "Iteration " + str(i+1) ##Print current loop
        GPIO.output(7, True) ## Turn on GPIO pin 7
        time.sleep(speed) ## Wait
        GPIO.output(7, False) ## Switch off GPIO pin 7
        time.sleep(speed) ## Wait
    print "Done" ## When loop is complete, print "Done"
    GPIO.cleanup()

## Prompt user for input
iterations = raw_input("Enter the total number of times to blink: ")
speed = raw_input("Enter the length of each blink in seconds: ")

## Start Blink() function. Convert user input from strings to numeric
Blink(int(iterations),float(speed))
```

Figure 11. Python code example. This picture shows a sample Python program to make the RPi "blink" an LED.

Data Collection

The primary sources of data collection were participant interviews collected before, between, and after makercamp weekends, participant observations collected during the makerspace investigation, and researcher debriefings. (See Appendix A3 for a detailed timeline of the data collection process.)

Interviews and Self-Articulated Relational Diagrams

Interviews were conducted in the week before the first weekend of makercamp, during the week between the first and second weekend of makercamp, and in the weeks following the second (and last) weekend of the makercamp. For the first and second interviews, participants were interviewed at their convenience, typically during lunch, an off period, or after school. The final interviews occurred during the weeks following the last weekend of makercamp as school had let out and scheduling became more difficult. Post-camp interviews were conducted at a local fast-food restaurant, a local coffee shop, a local library, a buffet pizza restaurant, and at the high school. For each of the participants, an approximately 15- to 30-minute-long semi-structured audio interview was conducted to assess the students' articulations of their relationships to making, CS, and technology-related elements. Concluding each interview participants were asked to sketch a diagram of themselves in relation to making and CS related topics.

Audio and Video Recording

Participants were audio and video recorded while participating in the makerspace investigation on both days of both weekends. Approximately 4.5 hours of footage was collected for each participant each day that the participant attended.

Behavior Analytic Debriefing

After the end of each makercamp weekend, i.e., on days two and four, the primary researcher debriefed with an expert behavior analyst in order to articulate and elaborate perceptions of behavioral relationships, especially functional relationships, and discriminations of participants' interactional histories. The first debriefing occurred in the verbal behavior lab with only the primary researcher and debriefer present. The second debriefing occurred in a local fast food establishment.

Data Analysis and Visualization

Data Analysis Procedures

This analysis was informed by the procedures of behavioral phenomenology as articulated by McCorkle (1978) and Day (1977). the behavioral–phenomenological underpinnings and procedures of this study were additionally informed by Lahren (1978) and Mascolo (1986). Moreover, the functional analyses of behavior presented by this study are modeled after those of Leigland (1989) and Dougher (1989), which differ to greater and lesser extents in intent and procedures from other functional analyses of behavior (cf. Hanley, Iwata, & McCord, 2003). All interview and relational map data was analyzed. Although all video data were analyzed for verbal behaviors, their antecedents, and consequences, only the two extreme cases of Sara and Osiel are presented for consideration (cf. Berland, 2008; Onwuegbuzie & Leech, 2007).

The behavioral–phenomenological analysis in this study consisted of:

1. *Behavioral–phenomenological analysis of interviews*. The researcher re-described the interviews phenomenologically, providing his discerned functional behavioral analysis. Namely, the researcher sought to discern contingencies controlling behavior (McCorkle, 1978, p. 53) and identify potential relational frames and derived relational responding, with a focus on deictic and other potentially identity-related relational frames.
2. *Providing an "ordinary account"* (McCorkle, 1978, p. 53). The researcher attempted to provide a detailed surface level description of stimuli, behaviors, and the environment (Day, 1977).
3. *Description of environmental circumstances*. The researcher sought to discern behavior–environment relations, i.e., the environmental contingencies under which behavior occurred (McCorkle, 1978, p. 56), including nonsocial aspects of the environment.
4. *Refinement into nuanced subcategories*. The researcher discriminated the most researcher-salient aspects of stimulus events, their subcategories, and their controlling relations to behavior (McCorkle, 1978, p. 57). In this study, the researcher refined subcategories of antecedents, behaviors, and consequences by disaggregating:

- antecedents as others' verbal behavior (OVB), environmental stimuli, and motivating operations (MOs)
- verbal behaviors by the commonly identified verbal behavioral types, mands, tacts, intraverbals, and echoics,
- contingencies by topography, specifically, as physical or social consequences (cf. Baum, 1974).

5. *Interobserver Agreement* – Though not commonly considered data for analysis, the inter-rater values in this study are perhaps more noteworthy owing to their relative uniqueness. Behavioral phenomenological studies such as McCorkle's (1978) did not provide or utilize interobserver agreement data, but rather emphasized the role of researcher discrimination training. However, owing to peer reviews of an earlier behavioral phenomenological study (Davis & Mason, 2016), this study provides inter-rater scores to help readers contextualize findings in the broader behavioral field. There are two sets of inter-rater data, one for interviews and one for verbal behavior analysis. Details for both are provided later in this chapter.
6. *Debriefing*. The researcher–observer debriefed with an experienced behavior analyst to "talk under the control of what has been observed," i.e., "to verbalize in recordable form whatever interesting discriminations were produced by the act of observation" (McCorkle, 1978, p. 56). These debriefing sessions provided, in part, a tentative outline for the behavioral–phenomenological description and description of environmental circumstances. This step is important owing to its immediacy and the potential for better capturing discriminations of in situ observations, as well as for adding behavioral–phenomenological validity.

Novel behavioral–phenomenological visualization. Behavioral phenomenology is not a new approach to understanding behavior (Day, 1977; McCorkle, 1978). Though some behaviorists are familiar with behavioral phenomenology, e.g. Sam Leigland (in conversation, at ABAI 2016), even at the University of Nevada at Reno, many behaviorists are not familiar with behavioral-phenomenology, which is commonly referred to as “the Reno method” (e.g., Dougher, 1989; S. C. Hayes, Blackledge, et al., 2001). Therefore, concessions have been made to improve readability and accessibility, such as adding interobserver agreement (IOA) measures.

Similarly, technology and behaviorism have not remained static since the inception of behavioral phenomenology. As such, this study acknowledges developments in behavioral research, such as the application of derived relational responding (Y. Barnes-Holmes, Foody, Barnes-Holmes, & McHugh, 2013) in the presentation of data. Similarly, this study leverages and expands adaptations to behavioral phenomenology. For example, in order to calculate IOA, a more quantifiable coding system was adapted to analyze participants’ verbal behaviors. This coding schema also facilitates the presentation of data in a more visually accessible format. Where this study presents a nonexperimental, functional analytic snapshot of a participant’s behavior in a makerspace context, multiple novel visualization techniques are used in attempts to behaviorally illustrate the factors influencing those snapshot responses.

The unique visualizations used in this study included:

1. *Self-articulated relations-to-CS diagrams.* The CS relations diagrams are analyzed and discussed in relation to the participant’s exhibited behaviors as well as in relation to any of the primary researcher’s discriminations of potential relational frames. This novel approach is informed by the “draw-a-scientist” methodology for assessing implicit biases with regard to science participation (Chambers, 1983; C. L. Mason, Kahle, & Gardner,

1991). *Participant Articulated Relationship-to-Self Diagrams*. Participants were asked at each of the three interviews to draw their perceptions of self in relation to STEM, CS, making, university, nerds, and other related topics. The participants' self-articulated relational diagrams were collected from each student before the first weekend of camp, after the first weekend of camp but before the second weekend, and after the second weekend of camp. An example of a relationship-to-self diagram was provided with initial recommended categories and potential relationship labels (See Appendix E2). Additionally, participants were encouraged to identify any additional relationships or descriptors they felt appropriate. In order not to prime responses with make and makerspace-related relationships, diagrams and interviews were collected away from the makerspace.[11] Diagrams have been transcribed from the participants' originals for legibility purposes. Diagrams and interviews are arranged in chronological order, three for each participant with any omissions noted and explained.

On the relational map provided to participants, ten example circles were listed (with the indication that participants should "feel free" to add more):

- Making things
- Making things with computers and other technology
- Programming
- Tinkering
- Electronics
- People who study computer science
- Nerds
- My ethnicity
- Other ethnicities
- College/University

[11] Owing to a late recruitment date, the participant Sara did not complete her initial interview until the first day of camp.

As well as ten example relationships (also with the admonishment to “please add any connections among circles [that] you like”):

- Like ***me*** / Not like-***me***
- Like / dislike; Love / hate
- Avoid / seek out
- Need/ don’t need
- Must do / cannot do
- Ability / no ability
- Interest / no interest
- Positive / negative
- No connection
- Other: <describe relationship>

Some participants responded to the relational drawing task as provided, i.e., they listed all ten example circles and limited themselves to the provided relationship descriptors. Other students took more liberty with the identified relationships and descriptors. More description is provided on a per student basis.

2. *Relational Frame Graphs.* Relational frame graphs are provided intermittently to highlight and illustrate participants’ articulated relationships. These graphs are intended to provide details, not to become the focus of the paper. For a closer examination of relational frames used to articulate maker-related molar and molecular behaviors see Davis and Mason (2016).

The relational frame graphs use a simplified set theory notation adapted from Hayes et al. (2001) and additional visual supports. For example:

$\in$ - signifies than an element is a member of a set

$\notin$ - signifies than an element is a not member of a set

$\ni$ - signifies than an element contains another element

∌ - signifies than an element does not contain another element

Solid lines connecting elements indicate that a relationship has been directly conditioned. Dashed lines connecting elements indicate that a relationship is derived, e.g., through combinatorial entailment.

3. *Interactional History Graphs*. The interactional history graphs consist of three circles. In the middle, the participant, to the left, "self", and to the right, connected with a dashed line, "others" (See Figure 12). The self-circle illustrates the participant's description of self in relation to positive (most likely reinforced) and aversive interactions with technology, CS, and making. The likely positive interactions are above the line with upward facing triangles and the likely aversive interactions are below the grey line with downward facing triangles. The positive interactions are tallied as positive numbers as they are likely reinforcing. The aversive interactions are tallied as negative numbers as they are likely punishing.

The size of the interaction-type specific triangles (i.e., technology, CS, and making) is percent relative to overall discriminated interactions from that interview. In an interview, where only six interactions could be identified as likely positive or averse, five positively valued self-technology interactions would produce a large triangle. By contrast, in an interview, where thirty interactions could be identified as likely positive or averse, five positively valued self-technology interactions would produce a smaller triangle.

Similarly, the circle for "others" illustrates the participant's discriminated positive and averse interactions for others (e.g., peers and family) with technology, CS, and making. The "others" circle is connected with a dashed line to the participant in order to suggest that effects arising from such actions are more likely the product of rule-governed and derived relational responding, rather than direct operant conditioning.

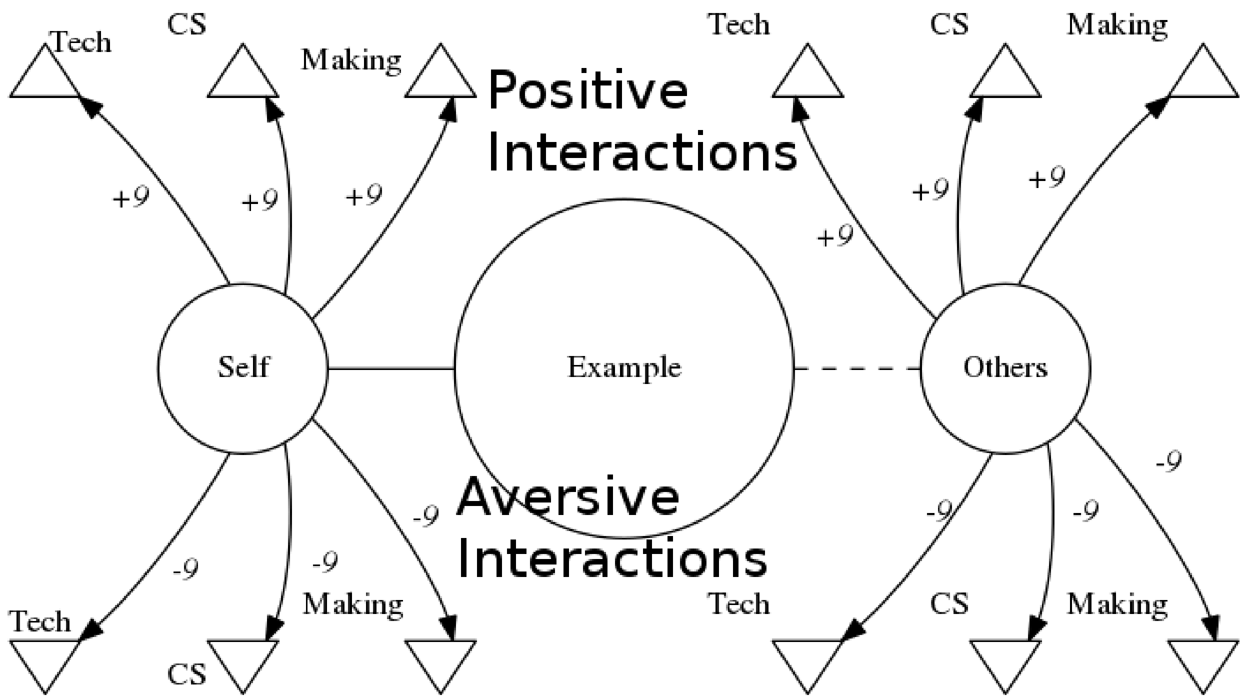

Figure 12. Example interactional history diagram. This example diagram illustrates the presentation of interactional histories with positive experience on top, aversive experiences on bottom, participant experiences on the left, and experiences of participant's' acquaintances on the right.

4. *Control Graphs*. The control graphs (or "snowmen") present the tallies of researcher discriminated control evident in participant's verbal behavior. Specifically, in the coding of participant's verbal behaviors, each statement was evaluated whether it suggested some, strong, or no identifiable reinforcing or aversive control from ten different sources: the physical environment, school interactional history, family, peers, the researcher, society (broad-based stereotypes – rule governance may or may not be media related), or media, representing social rules, such as stereotypes, propagated in television, film, or

video games. Each node is sized relative to total control discriminated for that participant. The shading of the node is based on percentages of aversive and reinforcing control evidenced for that node. The color is in the black-white spectrum on a percent additive Hue, Saturation, Value (HSV) scale, where 100% positive would be black and 100% aversive would be white.

For example, in Figure 13, out of all interview statements from which the researcher could discriminate control, a large portion (38) suggested control from the environment, whereby 32 elements suggested positive control and 6 elements suggested aversive control. The color of the node representing environmental control is slightly grey as a noticeable number of statements evidenced aversive control. Had all statements relating to environmental control been positive, the environmental control node would be black. Had they all been aversive, the node would be white. As such, aversive control only affects node size by adding to the total size. By contrast, positive control increases darkness and size of the control node.

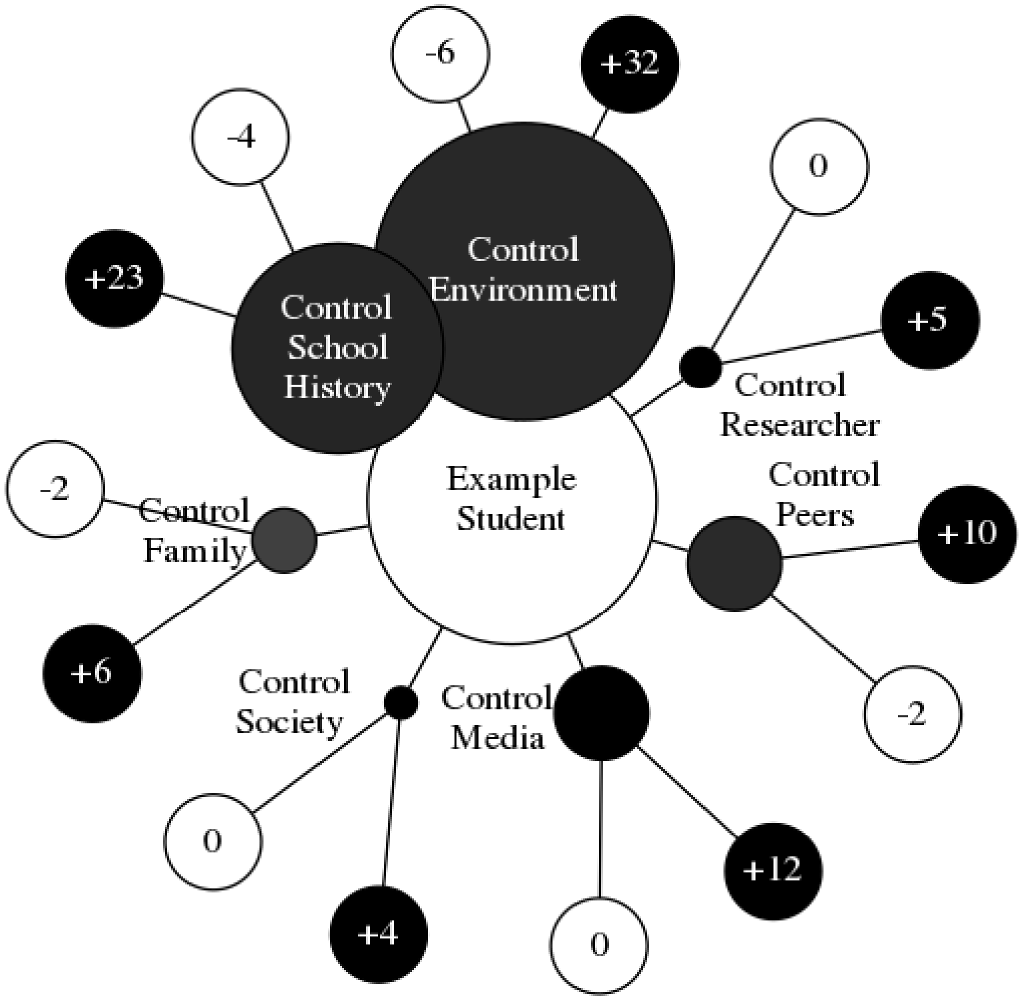

Figure 13. Example control diagram. These diagrams illustrate the sources of control influencing student's behavior as discriminated from interviews. The size of the second level circles represents relative frequency of articulation. Second circle darkness represents percent positive.

5. *Illustrating Verbal Behavior Flow*. Inspired by Lahren (1978) and Patterson (1974), the researcher attempted to illustrate relationships among antecedent, behavior, and consequence (contingency) classes (Skinner, 1957b). In the summary of findings, the researcher indicates the instructional design components identified as most salient to the development of physically grounded maker environments supportive of students' maker identity and skill trajectories. The researcher discusses relationships among participants'

CS and maker identity and skill behaviors as well as identifying the operants, especially, potential reinforcers, following the most frequently repeated maker identity and skill behaviors. (These graphs are in Appendix D.)

Classes of Behavior to be Discriminated

Although comparable past behavioral phenomenological research did not engage in a “hypothesis testing venture” (cf. Patterson, 1974, p. 901 as cited by Lahren, 1978, p. 65), emphasis has been given to selected target behaviors. Here, the selected target behaviors sought for discrimination, which may overlap, were broadly:

1. ***Identity-related behaviors***. Many of a number of molecular (micro) behaviors constituting larger, more longitudinal molar (macro) behaviors and response classes relating to or describable as identity and identity frames (Dymond & Barnes, 1994, 1995; Stewart, 2013). The discrimination of identity relevant behaviors was significantly dependent on the researcher’s previous discrimination training (Hays & Singh, 2012c; McCorkle, 1978). Also, special attention was given to self-referential statements (cf. Fies & Langman, 2011).
2. ***Relational framing***. The researcher has attempted to discriminate evidence of potential relational frames. This discrimination was only tractable for verbal behaviors. Special focus was given to identifying relations articulated by participants regarding CS, making, programmers, computer scientists, makers, self- or identity-related components, such as family and hobbies, and other potentially relevant references (cf. Cuero & Kaylor, 2010; Johnson et al., 2011; Zambrana & Zoppi, 2002). Moreover, special attention was given to those deictic relations evidencing potential characteristics of a phenomenological, noetic

(*noesis* → *noema*) relationship (Ihde, 2012, p. 26; cf. Moustakas, 1994, pp. 31–32). Namely, self-referential statements illuminating *how* the participant was experiencing the makerspace experience were noted.

3. ***Embodied cognition***. As commonly understood, cognition cannot be readily observed or discriminated from other behaviors, regardless through which epistemological lens it is articulated (cf. Skinner, 1984). Here, the observer made note of possible physically grounded verbal and nonverbal behaviors. This required explicit, elaborate description of behaviors, the physical environment in which the behaviors occur, and the intersection of the two (McCorkle, 1978, p. 61).

4. ***Common types of verbal behavior***. In order to provide clearer identification of verbal behavior types for pragmatic analysis of novice behavior in a makerspace, the study focused on the four most commonly discussed types of verbal behavior, namely echoics, mands, intraverbals, and tacts (e.g., Miller, 2006; Skinner, 1957b; M. L. Sundberg, 2016).

    a. *Echoics*. Echoics are behaviors that display point-to-point correspondence with another speaker's preceding verbal behavior. For example, if a parent says, "apple" and the child says "apple."

    b. *Mands*. Verbal behaviors coded as mands are emissions whereby the speaker makes a request, places a de*mand*, or gives a com*mand*. Questions are identified as mands as they represent requests for information.

    c. *Intraverbals*. Intraverbals refer to verbal behavior controlled by others' verbal behavior. Namely, intraverbals are influenced by other's verbal behavior and, more specifically, are under stimulus control of verbal behavior. Intraverbals do not share point-to-point correspondence with others' verbal behavior, such behaviors are echoics. Intraverbals commonly reference stimuli and behaviors not currently present. To be qualified as an intraverbal, antecedent verbal behavior (VB) should be present.

d. *Tacts*. Tacts function to label or describe stimuli present in the environment. Consequently, the absence of a stimulus is not a tact as referring to an absent stimulus could likely be the result of prior conditioning and intraverbal control. Tacts do not functions as commands or demands.

e. *Impure and hybrid VB.* For coding, verbal episodes were labeled by the VB types discriminable by the rater. Three columns were provided for VB type, and a fourth hyphenated VB could be added if necessary. The labels were used to identify VB characteristics present rather than simply being limited to exact matches. For example, if a speaker were to ask, "Do you like apple sauce?" and the participant replied, "Apple sauce?!" or "Sauce?" then the VB would be coded: a.) as an intraverbal, because it is influenced by the preceding statement, b.) as an echoic, because it replicates at least part of the earlier statement, c.) and as a mand, because clarification is being requested. (See Horton & Matteo, 2007).

Trustworthiness and Quality Assurance

This study provides qualitative trustworthiness in several ways (Hays & Singh, 2012a; Morrow, 2005). First and foremost, it should be noted that qualitative research should not be equated with subjectivity nor quantitative research with objectivity (Morrow, 2005, p. 254). Quantitative research is shaped for each field by the previous interactional histories of the members of its verbal communities (Kuhn, 1962). Owing to the previous interactional histories of researchers and the tools utilized, the depth of findings can be extended while narrowing the scope of possible findings (cf. Gödel, 1931). Behavioral phenomenology acknowledges that discerned interactions are shaped by the researcher's previous interactional histories (McCorkle, 1978).

Similar to bracketing in other qualitative, phenomenological studies (Hays & Singh, 2012b, p. 354), the behavioral–phenomenological researcher (cf. Day, 1969) provides a description of her or his previous interactional histories and concomitant verbal training in order to clarify the context of discriminated behaviors (Lahren, 1978; McCorkle, 1978). Also similar to other qualitative research, including phenomenological, "thick description" is a cornerstone of the behavioral–phenomenological approach (Hays & Singh, 2012a, p. 21); the first step of a behavioral–phenomenological study is to provide a very detailed, surface-level account of observed behavior (Day, 1977; McCorkle, 1978, p. 53).

Also increasing trustworthiness, behavioral phenomenology adds a layer of reflexivity (cf. Morrow, 2005, p. 254), whereby, the researcher debriefs with an experienced behavior analyst to clarify relevant discriminations, such as questions, reactions, and feelings, in response to participants (McCorkle, 1978, p. 181). The transcription and later analysis of these sessions by an external behavior analyst (here, a committee member) adds transparency and rigor to the study, limiting and questioning subjectivity while redirecting the focus to a functional analytic description of participant behaviors. This extensive metabehavioral analysis, similar to peer debriefing (Hays & Singh, 2012a, p. 211), of the researcher's ongoing analysis adds credibility to the study (Hays & Singh, 2012a, p. 200). Similarly, the study's calculation of interobserver agreement for approximately 10% of observational data (more than four hours) should bolster the study's credibility and confirmability (Hays & Singh, 2012a, pp. 208–209).

The study also maximizes trustworthiness, in that coherence (Hays & Singh, 2012a, p. 201) is established through a rigorously consistent epistemological and theoretical grounding for study; namely, the study is firmly grounded in radical behaviorist theory and its grounding is iteratively checked, refined, and verified throughout the research process.

Lastly, the study's validity builds on it social validity (Wolf, 1978). The study occurs in situ, within a natural context and is designed to provide ecological soundness (Mayer, Sulzer-Azaroff, & Wallace, 2014c, p. 65). By researching participants in an authentic context in order to address socially significant goals and facilitate socially important effects, the research project attains the social validity expected of qualitative behavioral research (Wolf, 1978, p. 208).

The Role of the Observer

Similar to the broader field of qualitative research (Hays & Singh, 2012c; Saldaña, 2009), the behavioral–phenomenological approach relies on the interactional history (Bijou, 1968, 1970) of the researcher (McCorkle, 1978, p. 54). Specifically, the researcher's ability to discern and discriminate elements of behavioral phenomena is shaped by the researcher's previous interactional history. Given the epistemological grounding of the study and its foci, including identity, it is necessary that the researcher disclose his relevant, personal interactional history (Prieto, personal communication, September 11, 2014). Additionally, it should be noted that, as with other behavioral–phenomenological research, additional behavior analysts may contribute to the functional analysis of the primary researcher's research-related behaviors.

Researcher and Debriefer Interactional Histories and Discrimination Training

The researcher for this study is Don Davis, a doctoral candidate in a school of education. Given his prior discrimination training, he discerns three behavioral repertoires most likely to control his discrimination of relevant stimuli: (a) training in the verbal behavior community of constructionists, (b) being an academic researcher focused on conducting research and developing instruction to improve participation of underrepresented students in computer science, and (c) developing fluency in the verbal behaviors of radical behaviorism and concomitant identity-related behaviors, such as increased social reinforcement within verbal communities of radical behaviorism and behavioral analysis. His prior conditioning in the verbal behaviors of constructionists has increased his discernment of the salience of building, making, creating, and related construction-like activities in educational contexts (e.g., Berland & Wilensky, 2015; Seymour Papert, 1996). Having worked with recent immigrant language learners, he also developed a behavioral repertoire adapted to identifying and discussing systemic and societal factors contributing to the underrepresentation of certain demographic groups in STEM fields (e.g., Cuero & Kaylor, 2010; Margolis et al., 2008; Ogbu, 1993; Varma, 2006; Zambrana & Zoppi, 2002). Lastly, he has evidenced a predilection for using behaviorist-specific terminology and socializing with behaviorists.

In keeping with past behavioral phenomenological studies (e.g. McCorkle, 1978), the primary researcher conducted a daily debriefing session with another behavior analyst in order to articulate a functional analysis of the observer's behaviors and discuss contingencies potentially controlling the observer's research behaviors. These approximately one-hour-long debriefings were conducted with a behavior analyst with more than twenty years of substantive behavior analytic practice. The debriefing behavior analyst has extensive experience in the functional analysis of severe behavior problems (e.g., self-injurious behaviors) and referent-based instruction. Lastly, following McCorkle (1978), a dissertation committee member provided a brief functional analytic synopsis of the debriefing sessions for inclusion. The committee member, a Board Certified Behavior Analysis Doctorate (BCBA-D), has worked extensively with the debriefer as well as the primary researcher. Neither the debriefer nor the committee member have explicit training in the verbal behaviors of constructionism or embodied cognition.

Inter-rater Reliability

In order to better situate this behavioral phenomenological study, inter-rater reliability data was collected. For those readers less familiar with phenomenological studies, it should be noted that in the broader field of phenomenology inter-rater reliability is uncommon but not unheard of (Marques & McCall, 2005). Similarly, the most familiar examples of behavioral phenomenology did not use inter-rater reliability (Day, 1977; McCorkle, 1978) though more quantitatively grounded behavioral phenomenological studies did (Lahren, 1978; Mascolo, 1986). The inter-rater reliability and tabulation of discriminations are not provided to cement statistical probability or guarantee infallibility of researcher discriminations, but rather to better situate and illustrate the behavioral phenomenological discriminations presented.

Interview Inter-rater Reliability

It was necessary to iteratively refine the inter-rater reliability training for evaluating interviews. The initial approach with verbal training with textual guidelines proved insufficient in supporting inter-raters. After three inter-raters failed to complete the inter-rater process, the interview document was simplified to a SurveyMonkey survey with multiple choice and short response categories specified in the training materials (See Appendix B for inter-rater training documents). For the interview inter-rater reliability checks, six inter-raters, at varying stages of applied behavior analysis (ABA) training, were solicited. It was posited that increased applied behavioral training would increase reliability. The inter-raters included one certified behavior analyst with more than thirty years of professional ABA experience, three graduate students enrolled in the Board Certified Behavior Analyst (BCBA) certification program, one undergraduate who had taken an introductory behaviorism class, and an independent rater in Brazil with a background in psychology.

The inter-rater process primarily occurred during a communal "rating party" at the verbal behavior lab where the BCBAs are trained. The certified BCBA, the three aspiring BCBAs, and the undergraduate student were given the written training materials. These materials were discussed with worked examples from the makerspace transcripts. Raters then spent approximately four hours evaluating 42 behavior clusters, approximately 17% of the 252 behavior clusters discriminated by the primary researcher from interview data.

In keeping with many behavioral research articles (Watkins & Pacheco, 2000), percent agreement was calculated for interobserver agreement. However, given the relative novelty of using IOA measures for phenomenology, the underlying focus on the rater's interactional history in behavioral phenomenology, and expected discrepancies in evaluations arising from differences in behavioral training (cf. L. L. Mason et al., 2016), raters were contrasted pairwise with the primary researcher, with the more experienced behavior analyst (Alonzo), and with one another for comparison purposes. The raters are arranged in order from the primary researcher, who was expected to be have higher levels of accuracy owing to familiarity with participants and the study, the senior behavior analyst, who was expected to have greater accuracy given his thirty-three years of ABA professional practice, then the BCBA trainees ordered from greatest to least amount of completed ABA course work, the undergraduate, and lastly the external rater, who described his behavioral fluency as "I study the mind" (a very non-behavioral position). At 74.2% agreement, the greatest percent agreement was between the primary researcher (Don) and the senior behavior analyst (Alonzo) with decreasing agreement then lightly correlating with decreasing behavioral training (See Table 1).

Table 1

Percent Agreement for Interview Inter-raters

	Don	Alonzo	Jennifer	Gabby	Rebecca	Williams	João
Don	-	74.2	67.1	59.5	47.2	52	59.5
Alonzo	74.2	-	62.7	63.1	51.6	58.3	52.4
Jennifer	67.1	62.7	-	57.5	47.2	44.4	53.2
Gabby	59.5	63.1	57.5	-	56.7	56.7	52.4
Rebecca	47.2	51.6	47.2	56.7	-	58.3	42.9
Williams	52	58.3	44.4	57.5	58.3	-	50
João	59.5	52.4	53.2	52.4	42.9	50	-

However, percent agreement has many observed limitations, including potentially inflated valuation of randomly selected matches as well as nonweighted valuations of nonagreeing items (Hallgren, 2012; Watkins & Pacheco, 2000). In the inter-rater process, raters were asked to discriminate whether participants' statements suggested histories of reinforcement, histories of punishment, or whether it was not possible to discriminate such histories. Consequently, as percent agreement does not weigh disagreements of *reinforcement* and *punishment* differently than *punishment* and *not discernible*, a weighted measure Cohen's Kappa was used to calculate interview analysis inter-rater agreement (Cohen, 1968; Gamer, Lemon, Fellows, & Singh, 2012) whereby the discriminating differences between *reinforcement* and *not discernible* might be very slight. For evaluating Cohen's Kappa, Landis and Koch (1977, p. 165) suggest that values 0.21 to 0.40 may be considered fair agreement, 0.41 to 0.60 be considered moderate agreement, 0.61 to 0.80 may denote substantive agreement, that higher scores might represent near perfect agreement, and that although such divisions are "arbitrary" they may be useful. When comparing interview inter-raters with a weighted Kappa, the primary researcher evidenced the greatest agreement (k=0.5, i.e., moderate agreement) with the more experienced behavior analyst and fair agreement with the two BCBA students furthest in their studies and the nonbehavioral reviewer.

Table 2

Kappa agreement for Interview Inter-raters

	Don	Alonzo	Jennifer	Gabby	Rebecca	Williams	João
Don	-	0.5	0.3	0.27	0.14	0.22	0.36
Alonzo	0.5	-	0.27	0.31	0.17	0.25	0.24
Jennifer	0.3	0.27	-	0.24	0.15	0.13	0.16
Gabby	0.27	0.31	0.24	-	0.21	0.2	0.24
Rebecca	0.14	0.17	0.15	0.21	-	0.16	0.08
Williams	0.22	0.25	0.13	0.24	0.16	-	0.25
João	0.36	0.24	0.16	0.24	0.08	0.25	-

Verbal Behavior Analysis Inter-rater Reliability

The raters for the analysis of verbal behaviors in the makerspace were Don, the primary researcher, Alex, a certified BCBA from another institution, and Gabby, a BCBA in training from the same institution as Don. The three raters evaluated verbal emissions for antecedent, behavior, behavioral content, and consequence type. In order to calibrate, the entirety of one day's discussion, by one participant, Sara, was evaluated by the three verbal behavior raters.

Interobserver agreement was calculated separately for constituent components and phases. There were two primary reasons for this separation:

1. The evaluation of antecedents, behaviors, and consequences were qualitatively different skills. Namely, labeling antecedents required *inferencing*, a problematic behavior for behavior analysts, whereas the labeling of behaviors should be more of an application of textbook-like definitions. Similarly, the labeling of consequences should have been a simple descriptive process, but may have relied on extraverbal cues not available in the transcript.
2. The identification of a *tact* is not inherently straightforward (Skinner, 1957a). Consequently, after discussion across raters a consensus was reached to use a functional definition, as the identification of extended tacts, i.e., stimuli not present in the environment, simply as tacts, would have obfuscated more than clarified patterns in verbal behavior emission type.

Antecedents. For assessment of interobserver agreement, raters identified salient stimuli prior to participants' emission of verbal behavior, comparing the 379 verbal emissions from Sara on Day 1. Specifically, raters identified whether the environment, other's verbal behavior (OVB), or "motivating operations" (MOs), a need without an immediately identifiable preceding stimuli, influenced participants' verbal behavior. Given the conversely concrete and inferred natures of environmental and MO antecedents, higher agreement was predicted for identifying environmental precursors and lower for MOs as antecedents. After clarifying with the inter-rater that multiple sources of control could be identified, the primary researcher and the inter-rater had 88.1% agreement on environmental antecedents, 79.9% agreement on OVB as preceding stimulus, and 75.2% agreement on MOs. (The agreement for MOs is has an artificially inflated appearance as agreement results from MOs relative infrequency.).)

Behaviors. In the first round of coding (379 verbal sequences), reliant exclusively on raters' prior interactional history and clarification of terms, inter-raters evidenced strong agreement on most verbal behavior (VB) types, except for tacts. Namely, raters varied in their coding of extended tacts, including descriptions of stimuli not in the environment, as tacts (cf. Skinner, 1957a). Consequently, for pragmatic reasons and the purposes of the study, i.e., identifying effects of physicality, the identification of tacts was limited to statements that functioned as labels of stimuli present in the environment. Differences in tact identification suggested seemed to relate to having been in the makerspace as only the researcher had been in the makerspace environment during the makercamp. Overall, agreement was high across raters and captures the emitted verbal behaviors with sufficient accuracy to illuminate the flow of novice VB in the makercamp (See Figures 66, 67 and Appendix D1).

Table 3

Interobserver Agreement Verbal Behavior

Core VB Percent Inter-Observer Agreement

Rater	VB Type	Don	Alex	Gabby
Don	Echoics	-	96.8%	94.1%
	Mands	-	93.7%	88.9%
	Intraverbals	-	88.9%	87.9%
	Tacts	-	82.1%	85.5%
Alex	Echoics	96.8%	-	93.1%
	Mands	93.7%	-	93.7%
	Intraverbals	88.9%	-	88.9%
	Tacts	82.1%	-	73.4%
Gabby	Echoics	94.1%	93.1%	-
	Mands	88.9%	93.7%	-
	Intraverbals	97.9%	88.9%	-
	Tacts	85.5%	73.4%	-

Consequences. Verbal behaviors were also classified as to whether the consequences, i.e., contingencies affecting their emission, were social or physical in nature. Similar to the discrimination of behavior types, coding was not an either–or binary but rather the consequence suggested social (i.e., having a conversation) or physical (e.g., being given a tool) effects. For inter-raters, there was 72.6% agreement for physical contingencies and 88.1% agreement for social contingencies.

Summary of Research Questions, Data, and Analyses

In summary, this study presents an examination of novice verbal behaviors in a makerspace. A behavioral phenomenological overview was used to illustrate the classes of antecedents, the types of verbal behaviors emitted, and the classes of the consequences following verbal behaviors. Specifically, the interviews were used to evoke participants' relationships to CS, making, and technology, and possibilities for derived relational responding considering the self as a relational frame. Identifying differences in personal histories and participants' relational frames informed the researcher's discrimination of CS and making related behaviors as they occur.

The molecular analysis of verbal behaviors, their antecedents, and consequences, provided a framework for understanding what prompts and maintains novice behaviors in a makerspace. The researcher could then identify to what extent physical variables, such as tasks and equipment, and to what extent social variables, such as conversations, are salient factors in influencing novices' immediate and longitudinal CS and maker behaviors. The analysis yielded a behavioral–phenomenological portrait of the makerspace learning landscape.

CHAPTER FOUR: RESULTS FROM INTERVIEWS

To identify relevant molecular and molar patterns of behavior, interviews were conducted to potentially evoke participants' articulation of interactional histories (Bijou, 1970) and sources of control (See Michael et al., 2011) influencing maker identity and skills, especially those related to CS. In doing so, multiple aspects of participant behavior were considered. In particular, the discrimination of molar or "meta" behaviors relating to identity were of particular interest. The research was designed to facilitate the identification of behaviors explicitly or implicitly indicative of derived relational responding influenced by identity-related behaviors. Further, the behavioral–phenomenological approach was used in order to discern potential relationships among identity, activity, and environment including relationships among social and physical characteristics of such. The overarching goals of this approach were to discriminate:

- Participants' and participants' social networks' histories with technology, computer science, and making.
- Sources of convergent and divergent control evidenced in participants' verbal behaviors, including interactional histories and relational frames.
- Behaviors indicative of derived relational responding, most especially those relating to self, physicality, identity components, technology, computer science, and making.
- Participants' relations to physical and social characteristics, including their form, rate, strength, and the relationship of those characteristics to skill and identity behaviors.

Interview - Presentation of Data

Interview data are organized by participant, presenting a discussion of each participant's pre-, between-, and post-camp interview in order. Each section begins with the participant's descriptions of self, as provided in self-drawn identity relationship maps and in oral interviews.

The more researcher-reliant observations and discrimination of behaviors and behavior-influencing factors are provided afterward. Following each interview, a tally and brief description of the interactional histories for the participant and participants' peers and family (labelled "others") are presented. At the end of each participant's section, a summary discussion of the participant's relational diagrams is presented, followed by a synthesis and analysis of researcher-discriminated sources of control.

Results are presented in the order of:

1) participant's self-depicted relational frames, their self-maker maps, which provides participant's depiction of self, limited or no researcher discrimination,
2) descriptions and brief analyses of participant's maker-related verbal behaviors as discriminated from interviews, including speech excerpts,
3) Researcher's discussion of participant's verbal behaviors, including articulated interactional histories of self and others with an interactional history graph, and
4) Researcher discrimination and analysis of participant's sources of control evidenced in the interview; and potential relations to CS, technology, and making trajectories.
5) The presentation of findings can also be described as greatest to least participant articulated.

The self-depicted relational diagrams are presented concomitantly with interviews in the order of: Luis, David, Osiel, Sara, Lili, and Yesenia. The presentation of diagrams and interviews is purposeful. As Yesenia's diagrams are the most novel, they have been placed at the end of the self-depicted relationship diagrams section. As STEM engagement, CS matriculation, and makerspace participation are frequently discussed with regard to the underrepresentation of women, the other female participants are listed directly preceding Yesenia and following the males.

Interview examples are provided with the diagrams in order to facilitate comparison of the two modalities: participants' direct depiction of self, as evidenced in the relationship-drawing task, and participants' less direct depiction of self in relation to other elements, as evidenced in the oral interview.

Luis

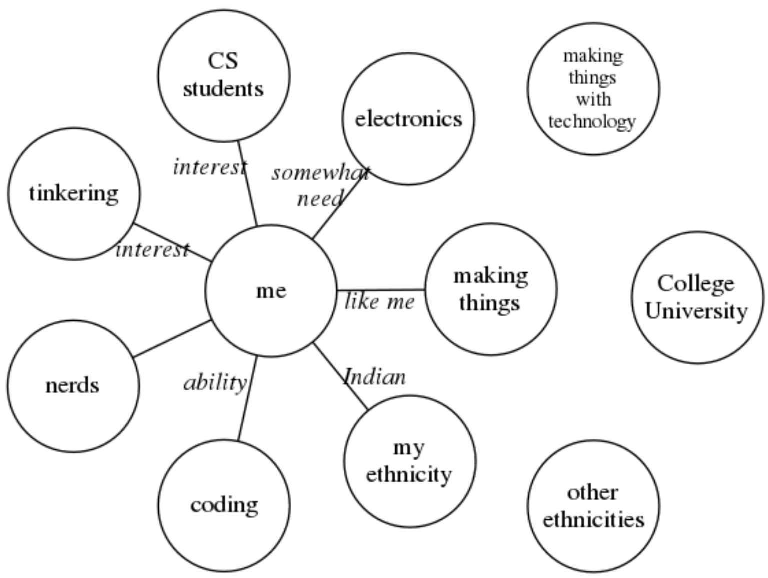

Figure 14. Luis's self-articulated relations pre-camp. This diagram reproduces Luis's pre-camp depiction of his relationships to topics possibly influencing interest in CS and making.

Luis Pre-Camp

Prior to the camp, Luis indicated that he was "not entirely sure of the type of person who creates with computers." When asked whether there was a stereotype of such individuals, he responded simply with "no." When prompted to describe whether he was that type of person, he indicated "sort of, yes." Similarly, when questioned about the type of people who study CS, Luis indicated that "they're just regular people" who "want to" and "take interest in it." He then noted that he was “somewhat but yes” that kind of person and that he did “enjoy using computers and stuff like that.”

The first relationship Luis discriminated between himself and computers was that he “want[s] to play video games, look at videos, or talk to [his] friends” on the computer. When pointedly asked when he made things with computers he answered “we did with school. I mean…” Then when asked for specific examples, he described web design and biology as he made PowerPoint presentations in biology. Then he added graphic design where he had to “make posters [and] things like that”.

In the preliminary interview, Luis did not provide many examples of projects he had made. Similarly, he did not, and possibly could not, recollect artifacts that his friends made with technology, except for a friend of his that made videos of game play of “just…like regular video.” When further pressed to describe the projects he had made with technology and to describe his friends’ reactions to those projects, Luis indicated that “some of the stuff [he’d] made [is] not really complete” and that he “never completed the projects for [him]self,” though “sometimes [people] like what [he] make[s].” Then when pressed, he could recollect that his friends had liked pixel art, a recent school project.

When asked about his family, Luis indicated that his mother “admires the stuff that [he] do[es]” and that “she thinks it’s really cool.” Upon being asked to describe his mother’s relationship to technology, Luis indicated that his mother had her own website. Though directly following that assertion, when asked to tell the researcher “a story about a time when someone [Luis] knew made something with computers or technology,” Luis indicated that he “[couldn’t] really think of a story made for that [sic].”

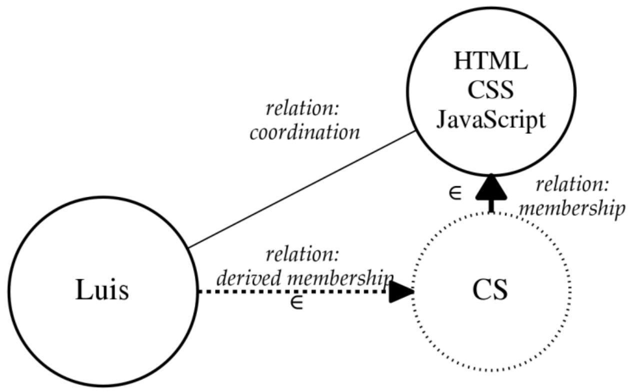

Figure 15. Luis's derived relation to CS. This diagram depicts Luis's articulate direct relationship to using HTML, CSS, and JavaScript, and a consequent derived relationship to CS.

Following that assertion, Luis noted that his mother used a program to make websites. Towards the end of the preliminary interview, when questioned as to whether he had the sort of experience that would lead someone to be a programmer, he indicated that he had "[made] websites like, you know, coded" using HTML, CSS, and JavaScript (Figure 15).

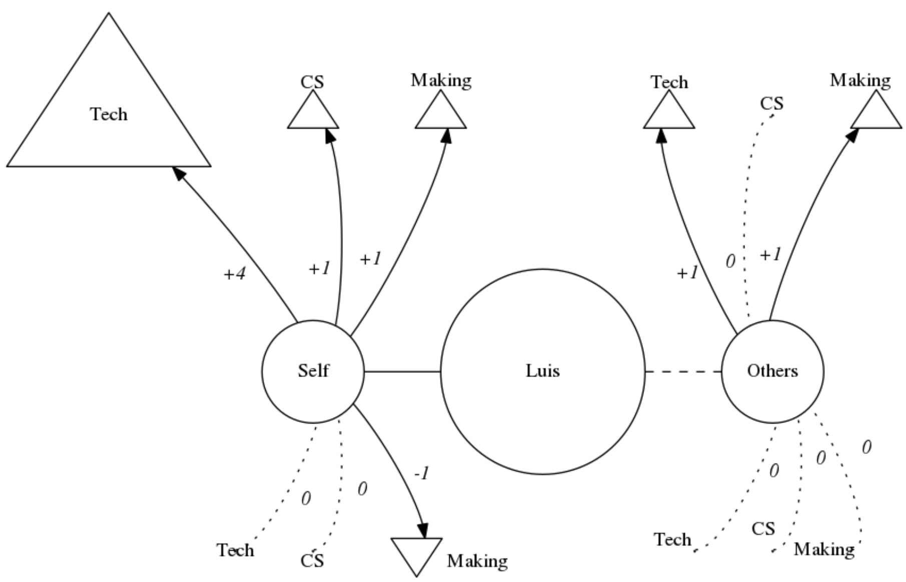

Figure 16. Luis's pre-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Luis's pre-camp interview.

Luis's pre-camp discriminated interactional history. The first interview with Luis revealed a history with relatively positive interactions (+4) with technology and only one discriminated punishing experience (-1). Luis's answers suggested limited, but some, history for himself and others with CS, technology, and making. Indeed, CS, making, and technology did not seem to be coordinated frames of reference, as he did not discuss websites in relation to making, but rather, only in direct elicited coordination with programming (See Figure 16).

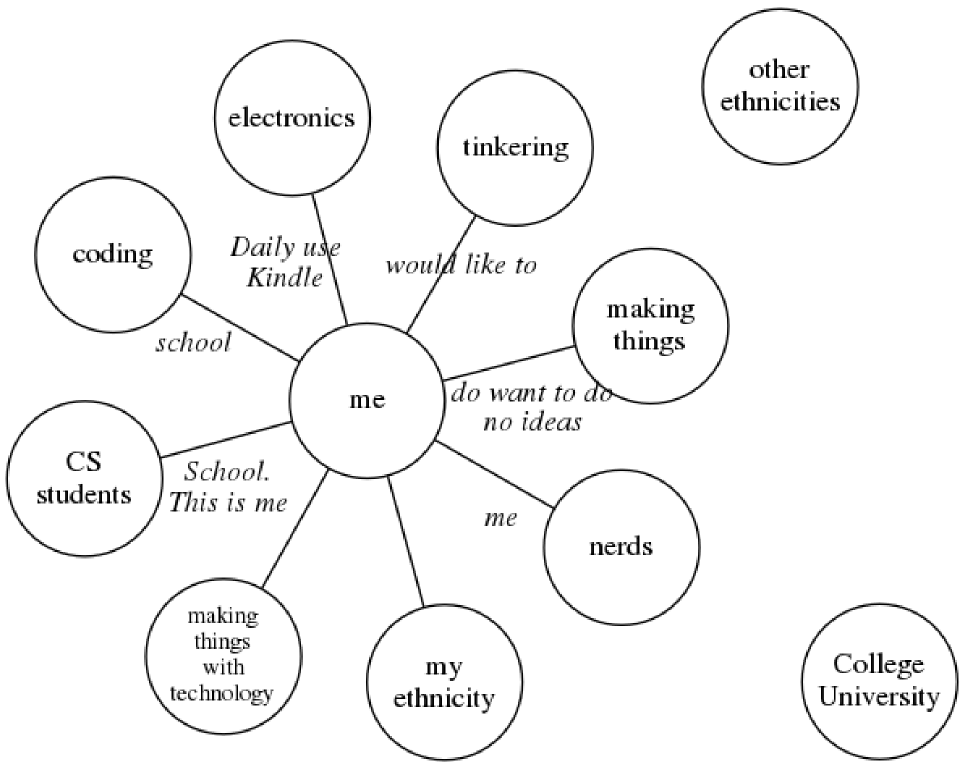

Figure 17. Luis's self-articulated relations between makercamp weekends. This diagram reproduces Luis's between-camp depiction of his relationships to topics possibly influencing interest in CS and making.

Luis between Makercamp Weekends

During the week, between the two makercamp weekends, participants were interviewed. Foremost among the interview questions were questions regarding students' perceptions of the makerspace, the other makers present, and whether students predicted that they would return to the makerspace. In the course of one response as to whether he would return to the makerspace, Luis communicated that he would return, but then immediately retracted that assertion, "On my own, yeah. No, because it's a little bit far." He then continued noting that "and at the moment I don't really have anything I want to make so."

In order to ascertain the consequences, i.e., operant conditions, following his makerspace visit, Luis was asked about his mother's response to his visit. Luis stated that he had talked to his mother about the camp and she "thought it was pretty cool" and that she wanted him "to go more to it…to learn more about Raspberry Pi." After which, Luis observed that one of his friends had offered to teach him about the Raspberry Pi and the Arduino.

Luis and making. Luis was then questioned as to what type of people are makers to which he indicated, "Anybody who wants to make something is a maker." He then answered that "yes" he was a maker, but "no," he did not have anything he wanted to make at the moment. Next, he elaborated about what might "inspire" him to make more and stated that it depended "on what [he's] interested in right now" noting that he "want[ed] to go into" animation and that he would start "making stuff like that." Later in the interview, when prompted to describe whether he had explored the makerspace, Luis indicated that he had "looked at" the tools such as the laser cutter and 3-D printer. He then recounted that he had "always" used a 3-D printer in middle school and that he had made "contraptions" and had "had a lot of ideas in middle school but [that he] kind of lost the interest," noting that he "still want[ed] to do something like that but [that he] kind of lost the ideas." He also indicated that his loss of ideas might "sort of" be related to the fact that he was not around 3-D printers as much.

When the researcher queried Luis as to whether the makerspace activities were "engaging." Luis replied, "They were a bit." The researcher then sought to ascertain whether the activities were perceived as difficult or challenging to which Luis responded that the difficulty with Scratch GPIO was "trying to find out what part of the program does what." Luis then continued that he "prefer[red] more typing of…programming not the drag and click." When asked if Scratch GPIO (i.e. the drag and click) was too difficult he indicated "no." Upon being questioned as to why he preferred typing, Luis indicated that he had "had more experience with typing" so he was "more comfortable with typing." When prompted for a description of what programming he had done before, Luis asserted, "Well, it was, you know, it was *not Python*."[12] He then restated that he "just prefer[red] typing more than drag and drop [sic]." He did not and possibly could not articulate more as to his aversion to drag-and-drop except when prompted as to whether he was averse to the child-friendly interface with the "spinning kitty" he stated, "Nah. No, that's not it."

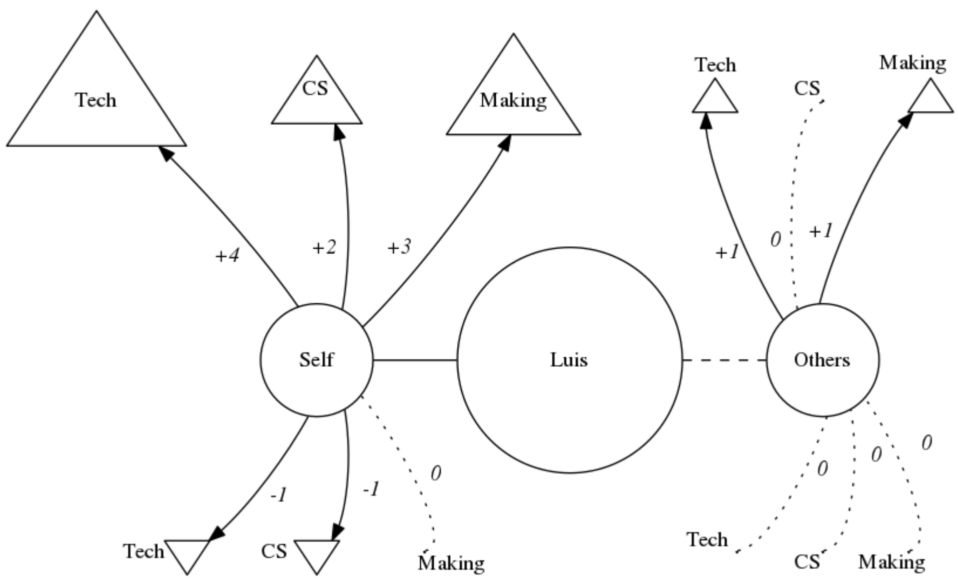

Figure 18. Luis's between-camp discriminated interactional history. This diagram illustrates the interactional history discriminated in Luis's between-camp interview.

[12] Emphasis added by researcher

Luis's between-camp discriminated interactional history. In the between-camp interview, there were more positive discriminated interactions for Luis with technology, CS, and making (+4, +2, +3) than aversive (-1, -1, 0). As with the pre-camp interview, Luis articulated multiple positive interactions with technology (+4). In this interview, Luis identified slightly more interactions with CS, noting one more positive and one more aversive experience than in the initial interview. Similarly, perhaps owing to an increased saliency of making, he indicated more positive interactions with making. More pointedly, the temporary burst in positive making discriminations (from +1 pre-camp to +3 between-camp, then to 0 post-camp) resembles bursts of increased emission frequency following periods of reinforcement (Ferster & Skinner, 2014, p. 140; Staddon, 2014, p. 58).

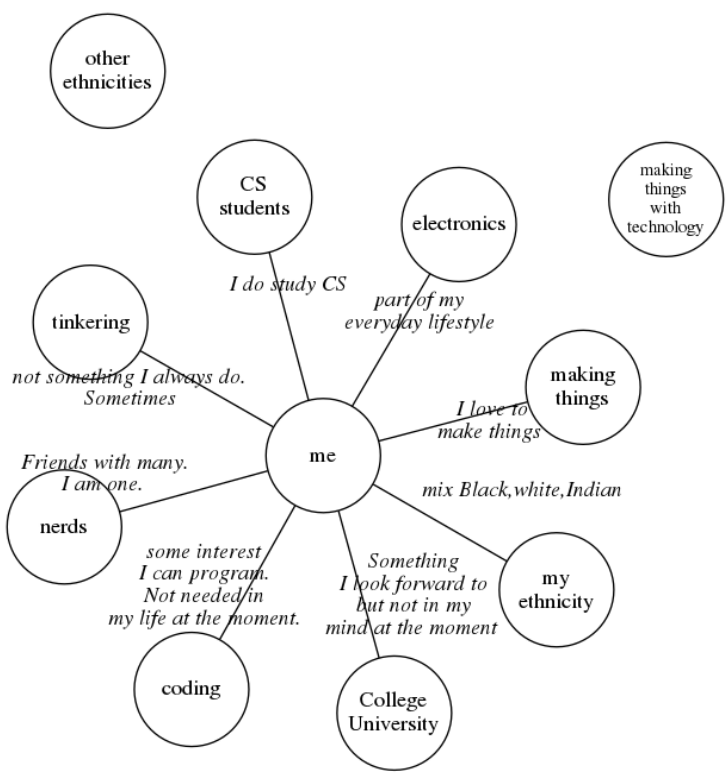

Figure 19. Luis's self-articulated relations post-camp. This diagram reproduces Luis's post-camp self-depiction of his relationships to topics possibly influencing interest in CS and making.

Luis after the Makercamp

Luis did not attend the last weekend of the makercamp. When asked why, he indicated that his mother had let him sleep in after he had stayed up late on the computer.

Luis, Self, and Identity. In the last interview, Luis was encouraged to specifically describe who he is. He then reported that he was "somebody who likes to try new things if it's there [sic]" and that he tries "to think out of the box" emphasizing again "I do try to think out of the box."

Given the discussion of nerds and their role in CS culture, Luis was asked whether he was a nerd. He replied that he was not sure what it means to be a nerd, but that "when you think of nerds, you see someone who knows computing and doing programming and stuff like that" and concluded by asking, "But what does it really mean to be a nerd?" The researcher then rejoined querying, "So, is that person you? You said a nerd was somebody who does computers and programming." to which Luis replied, "I guess so, yeah." He observed that he "can program" but not in his "free time." He then indicated that he could program HTML, CSS, Java, and JavaScript. He also indicated that he had learned to program Java in a one semester course with Mr. Jones.

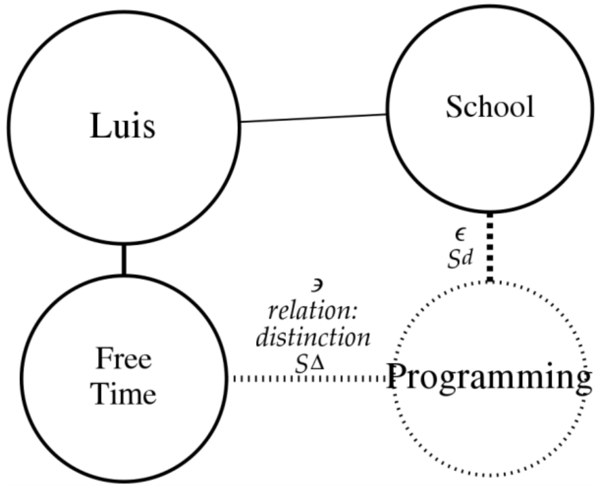

Figure 20. Luis's contextual relations to programming. This diagram illustrates Luis's description of programming as not belonging to the class of free time activities.

The researcher then inquired "for a semester, and so did you develop the skills that helped you feel secure as a programmer?" To which Luis replied, "Yes." Then in response to the researcher's query, "But what did you do in his class? What kind of projects?" Luis then explained:

> *We did things like for loops. I can't remember. We made programs where if we like put in a number then like— I can't really explain it. I kind of forget exactly what we did but I mean we did. I just don't remember.*

Concluding the interview, Luis was asked about his plans for the future and if they involved programming or CS. He indicated that he wanted to study aerospace engineering, which would involve programming. When asked if he would return to the makerspace, he noted that it was "very unlikely" unless he thought "of something that [he] really wanted to be done, then maybe."

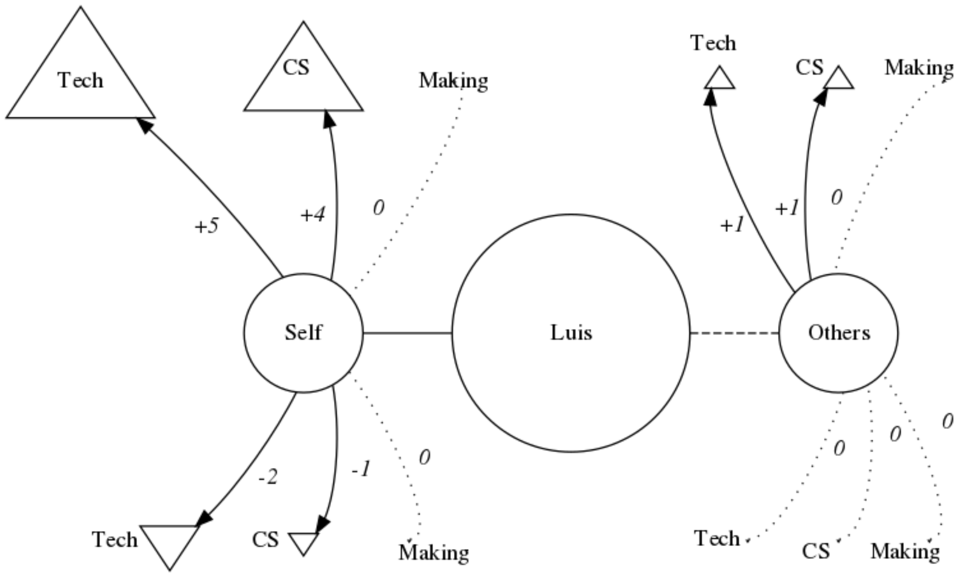

Figure 21. Luis's post-camp discriminated interactional history. This diagram illustrates the interactional history discriminated in Luis's post-camp interview.

Luis's post-camp discriminated interactional history. In Luis's post-camp interview, his statements identified more frequent articulations of a reinforcing history with technology and CS (+5, +4). Though not pronounced, a greater aversive history of interactions with technology and CS was also evidenced (-2, -1; See Figure 21). The evocation of interactions was as much a product of the environment as what occurred in the environment: Luis's exposure to the CS-imbued makercamp environment resulted in increased "favorable" recall of prior, non-makercamp CS-related activities. As such, Luis's increased discrimination of positive interactions with CS may, nevertheless, be indicative of the strength of control exerted by the makerspace environment.

Luis's Relational Diagrams

In the self-drawn relational diagrams, Luis most frequently responded by drawing a connection to the majority of document-provided identity elements and then he progressively added more description to each relationship label. Before the camp, he listed seven of the ten relationship elements, leaving out connections to "making things with technology," “College/University,” and “other ethnicities.” Only between the two camp weekends, did he draw a connection to making things with technology. Only after the camp had ended did he draw a connection between himself and “College/University,” whereby he added the relatively lengthy descriptor, “Something I look forward to but not in my mind at the moment.”

Table 3

Luis’s Self-Articulated Relations

Element	***Before MakerCamp***	***Between MakerCamp Weekends***	***After MakerCamp***[13]
Programming	Ability	School	Some interest. I can program. Not needed in my life at the moment.
CS Students	Interest	This is me.	I do study CS.
Making things	Like me	Do want to do; no ideas	I love to make things.
Making things with technology		Daily thing. Mainly at school.	
Tinkering	Interest	Would like to, but nothing to tinker.	Not something I always do. Sometimes.
Ethnicity	Indian		Mix black, white, Indian

[13] Luis did not attend the second weekend of the makercamp. He indicated that he had slept in.

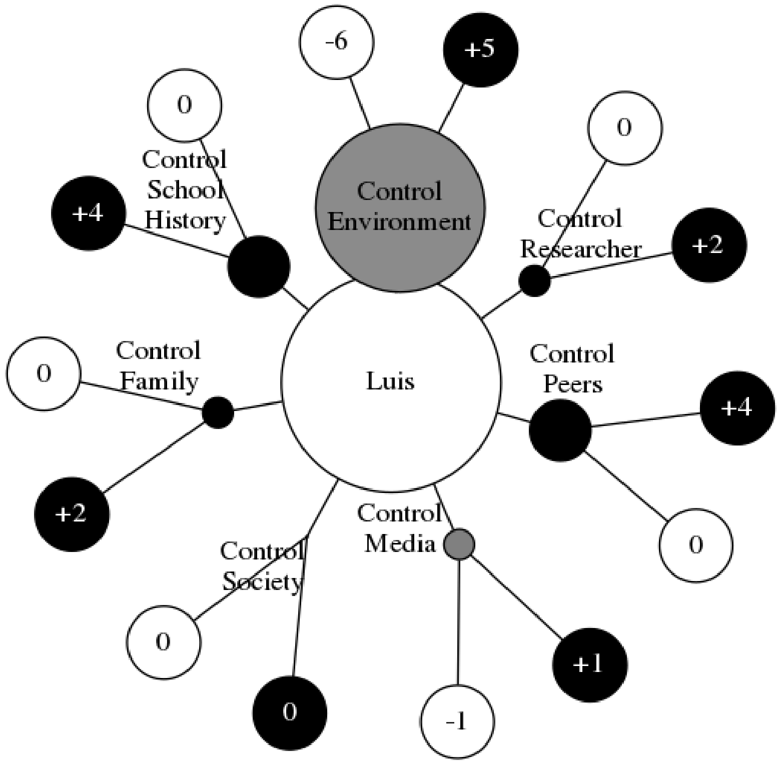

Figure 22. Luis's sources of control. This diagram illustrates the sources of control influencing Luis's behavior as discriminated from Luis's interviews by the researcher.

Luis's Sources of Control

In analyzing Luis's VB, the environment, as with other participants, was identified as the greatest controlling influence. The overall effects of the environment seemed to be averse. Specifically, the higher tally of statements suggesting averse control of the environment arose from Luis's antipathy to the Scratch programming environment.

Further, given the discriminated control of peers (+4) and school history (+4) relative to that of the researcher (+2), peer-preferred and school-familiar environments may be more likely valuated as positive. Conversely, elements in a frame of distinction or opposition to school or peers may more likely be perceived as aversive and responded to aversively.

David

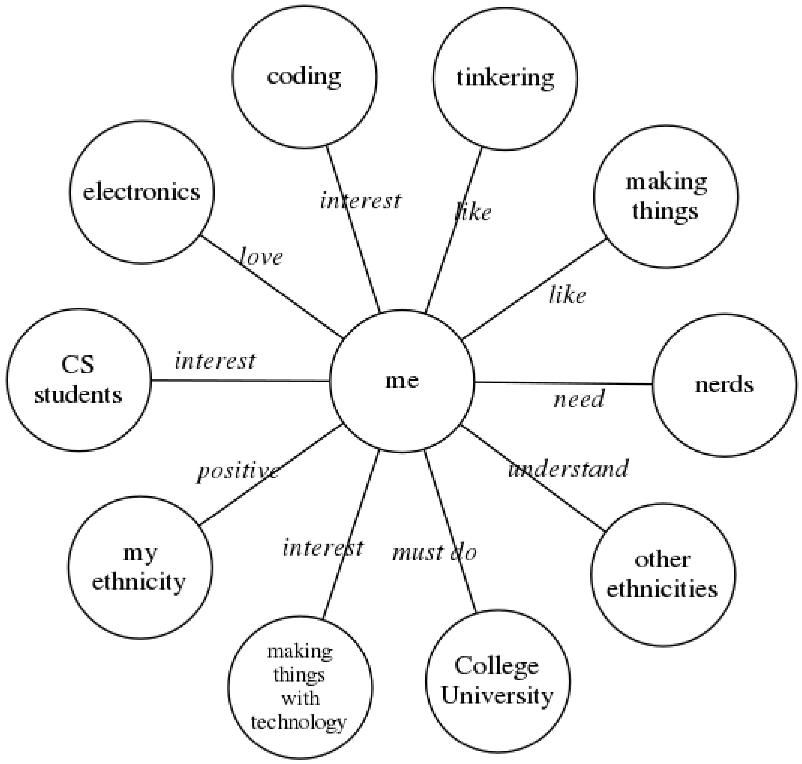

Figure 23. David's self-articulated relations pre-camp. This diagram reproduces David's pre-camp self-depiction of his relationships to topics possibly influencing interest in CS and making.

David Pre-Camp

As in the other interviews, the discussion began with David being asked to describe his perception of "the kinds of people who create things with computers." David then elaborated, "Creative people, people who enjoy science and math, that type of stuff" were the types of people who create things with computers. When prompted if he were that type of person, David affirmed that "yes" he was as he was "really good at math." David expounded, "So it has to do with numbers and stuff, figuring out types of numbers and I'm good at that" (cf. Figure 24).

Subsequently, David explained that with regard to computers and technology "[he'd] always just been interested [in] like how does it work, what makes it work." He elaborated that "ever since [he] was little [he would] like take apart a computer just to see what was inside."

Moreover, he continued explaining that interest in the inner workings of computers had motivated him to take the web design class with the researcher.

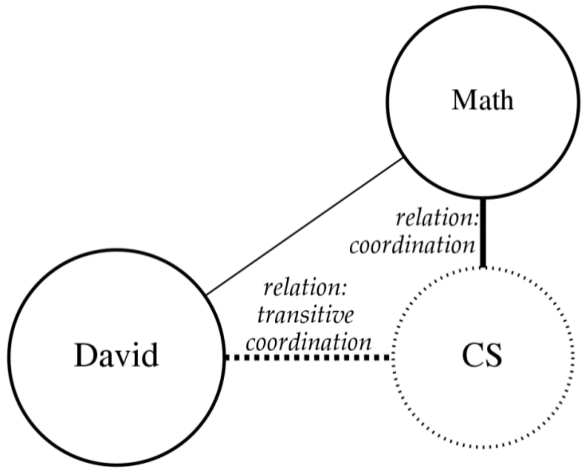

Figure 24. David's relationship to CS. This diagram illustrates how the directly identified relations between David and math, and math and CS result in a derived relationship of coordination to CS for David.

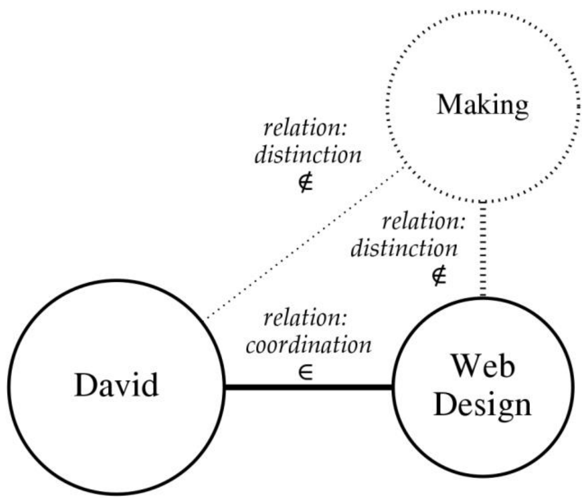

Figure 25. David's relation to making with computers. This diagram illustrates the relationships articulated whereby he was in a frame of coordination with web design but not making with computers – and, as such, making with computers is not in a frame of coordination with web design for David.

The researcher then requested that David recount what he had made with computers. David replied that he had "never" made things with computers but rather "more so like websites that [he] like[d] to go on and figure out the coding." He then explained that he had "played with" Web page creation websites "and they were only free trials" (See Figure 25).

David and Others. When describing familial and social relations to making, David stated that his friends did not make things with computers and technology nor did he show them what he had made with computers and technology or talk to them about it. However, David divulged that his grandmother and mother were "really up for it" and that they made him "do extra classes like [the researcher's] Saturday stuff." He further revealed that his grandmother and mother encouraged him by admonishing that "[David] need[ed] to go and do it so [he could] show" them. He summarized that "they really push[ed him] to do a lot of things like that."

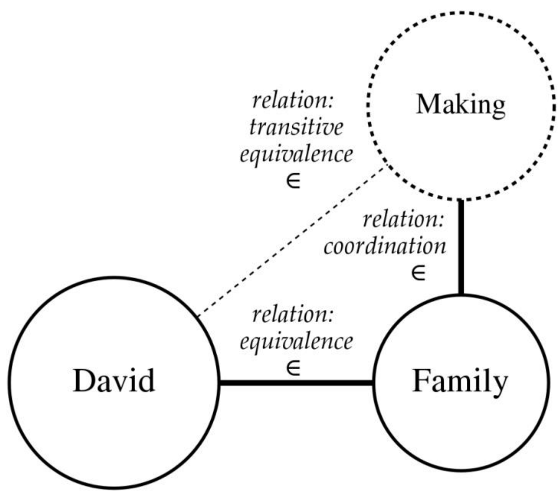

Figure 26. David's familial relation to making. This diagram illustrates how David's direct relationship of equivalence to his family, and a relationship of coordination between family and making lead to a derived relationship to making for David.

Similarly, when asked if any of his friends or family were makers, David indicated that his grandmother was "big on building stuff. So that's where [he] get[s] it from" (cf. Figure 26).

He expressed that his grandmother “has done a lot of things” and that “she likes working on cars mostly because that’s what her dad used to do.” David then elaborated that the making extended beyond cars and that “if something ha[d] to be done in the house like the fence, [they] had to build a bigger fence.” He then continued that in such instances his grandmother would have him “go around with the numbers because that’s what [he’s] good at.” David also adds that he discovered he was good with numbers when he was given a placement test in middle school.

CS Perceptions. When asked “Who are the types of people that are computer programmers?” David depicted computer programmers as:

> *Those people are the ones who do well in school. The type of people, they are like quick in their mindset, they know how to figure something out without having to stretch it out like asking somebody all the time. They can ask one person then understand it and move quickly.*

Then in response to the follow up question if he was such a person, David explained, “Yeah, I ask for help here and there like doing full on coding, but after a while I understand it I’ll refer to my notes.”

After being prompted to explain the experiences that might lead someone to become a programmer, David postulated that the interactional histories that led people to become programmers involved “messing with computers a lot.” Namely, for those individuals who are “always on the computer and just find it interesting; like more so behind the scenes and not just be[ing] on the internet.”

David then recalled a specific instance from his childhood that he indicated was seminal in developing his interest in computers. Specifically, David recalled his father having spilt water on the computer. Then after a press of the power button did not revive the computer, David had to venture to the computer store with his father to acquire parts, when he then realized that many parts were required to make the computer function. David then recollected the clerk at the computer store who explained “software within itself” and showed David “if you press this key it does this.” In describing the encounter, David highlighted that he “just found it really fascinating.”

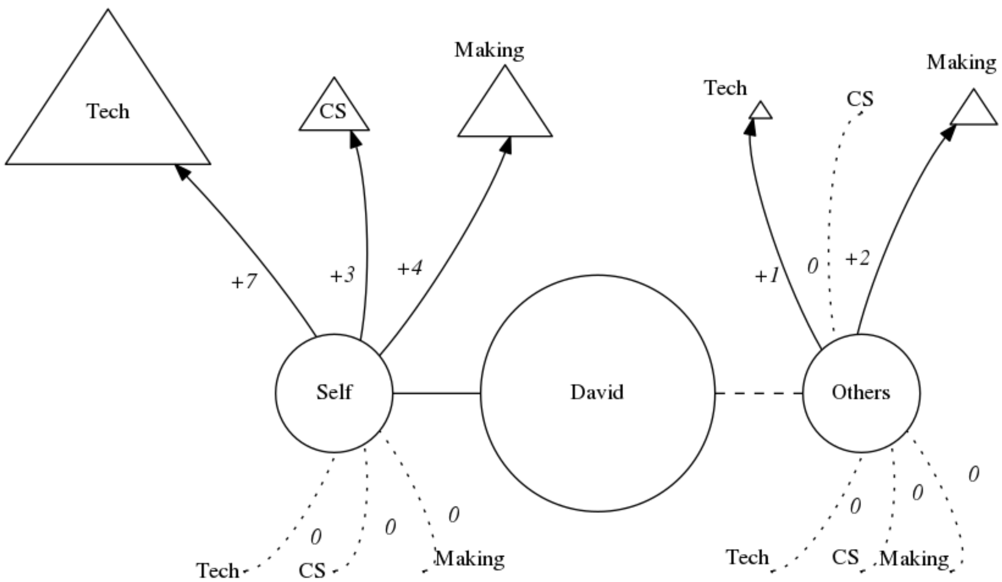

Figure 27. David’s pre-camp interactional history. This diagram illustrates the interactional history discriminated from David’s pre-camp interview.

David’s pre-camp discriminated interactional history. In David’s pre-camp interview, he provided a history that highlighted positive interactions with technology, CS, and making activities (+7, +3, +4) and did not detail any aversive experiences for David or his acquaintances. During the interview, David described strong familiarity with technology, making, and CS. Similar to other participants, his discussion of technology, especially in relation to web design, may have arisen, to some degree, owing to his experience with the researcher as a web design teacher, i.e., the researcher served as a signal, i.e., an S^D, for Web-design related verbal behavior.

David’s discussion indicated that his family, especially his grandmother, had a strong affinity for making and problem solving, which suggests a strong history of reinforcement for making, at least for his family.

David between Makercamp Weekends[14]

When asked about his perceptions of the makerspace, David provided some detailed responses. He began by noting, “It was fun for the most part, had a little confusion the second day when we were doing the light but I got it.” He then elaborated, that he “liked building with the motors and getting to build and all that.” Next, he observed, “I liked how people were actively helping. I liked that part. Like with parts I didn’t understand [that] they knew, they somewhat helped, bit it’s mostly about figuring out so I did enjoy that. Everybody was friendly and helpful.”

The researcher then inquired as to what David had told his friends and family about the makerspace. David detailed that he had told his family:

> *About the class and they were happy about that but once I learned like about the memberships and the 3-D printers and all this stuff, they were like “Oh yeah, you should do that so you could teach us how to do it.” And so they were really excited about that and they were happy that I was learning it.*

After which, the researcher commented that David had mentioned makers in his family. Again David indicated that his “grandma makes everything,” expounding that “she tries to make everything herself,” and elaborating “She hates to give up. It’s like one of her biggest fears or something—she doesn’t like it.” As in the first interview, David observed that his grandmother

[14] As the interview was conducted outside, no relational map was collected

"likes to learn and things and mostly do it herself" and he then infers "so I think that's where I get it from."

Given that a key focus of the study was programming-related behaviors, David was then prompted to describe if and how his perceptions had developed with regard to programming. David stated that he "still like[d] it" and went on to explain that he thought he had done "a fair amount." Although, he added that he felt as if he "wasn't moving fast enough to get more things done." He also indicated that he would have preferred to "embrace the time and not just…[spend] the whole five hours that we were there on one little thing."

At the conclusion of the interview, David asked if the makerspace would be offering any more classes.

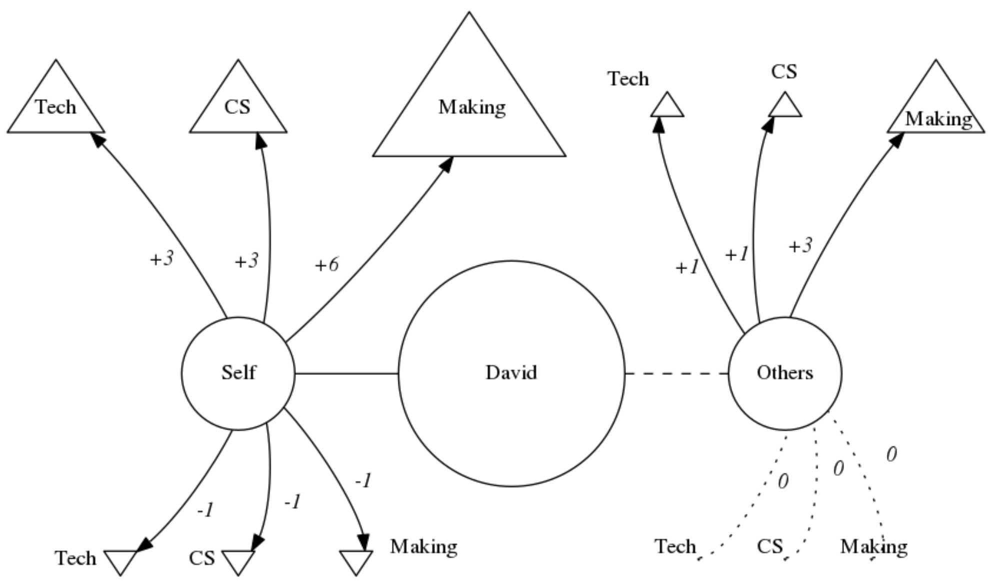

Figure 28. David's between-camp interactional history. This diagram illustrates the interactional history discriminated in David's between-camp interview.

David's between-camp discriminated interactional history. David's between-camp interview detailed a personal history with positive interactions for self with technology, CS, and making (+3, +3, +6), though aversive experiences became discernible as well (-1, -1, -1; See

Figure 28). In particular, this interview highlighted the increased saliency of his and his family's interactional history with making (cf. Johnston, 2014).

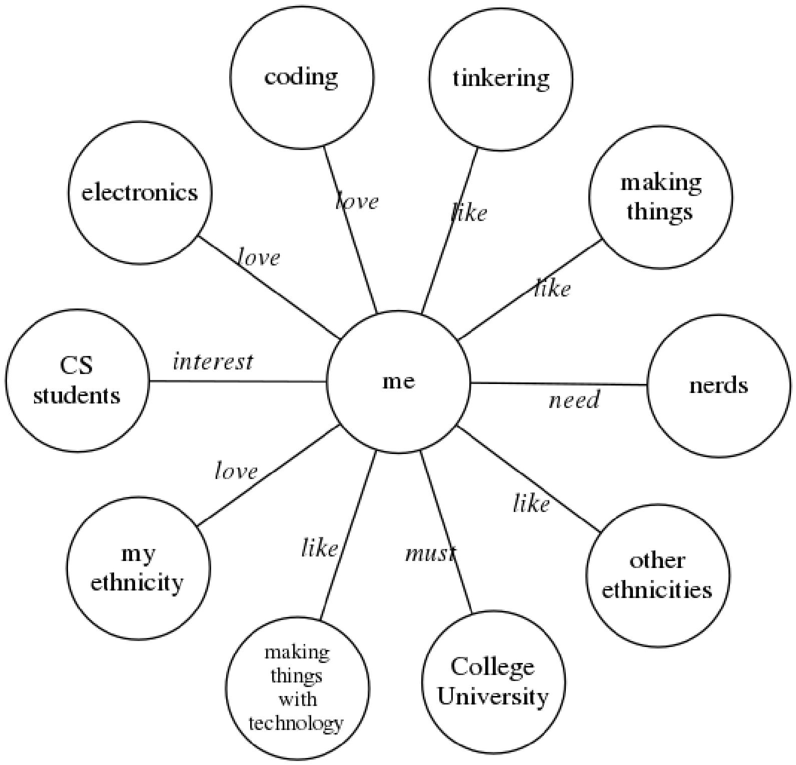

Figure 29. David's self-articulated relations post-camp. This diagram reproduces David's post-camp depiction of his relationships to topics possibly influencing interest in CS and making.

David after the Makercamp

David missed the last weekend of the makercamp. When asked why he had missed the last weekend, he explained that he had to work and that he had to babysit before he went to work. He also noted that he had planned to make it, but that he had been too tired, as he had worked until close the night before.

For the last interview, David brought a female friend. She sat at a separate table in the local fast food dining establishment. In order to ascertain what David had shared with his friends about the makerspace and potentially facilitate the discrimination of any potentially reinforcing social contingencies, the researcher queried David regarding what he had told his friend about the makercamp and makerspace. David replied that he had told her “everything we’[d] been doing.” When pressed for an example, he expounded with “the Raspberry Pi” and “the PiBrella”, two pieces of technology we had used. The researcher then queried what the friend had said to David about the makercamp, David remarked that she had asked about how it works. The researcher then queried if David had spoken to any of his other friends about the camp and he attested that he had not talked to his other friends since the camp, approximately three weekends prior.

The researcher then questioned David about his family’s responses to his makerspace attendance. David explained that his mother and grandmother had asked if he was going to continue with the camp and if it would help him with what he was going to do in the future. To which he replied, “Yeah, sort of. There’s more than one little lesson.” The researcher then followed by asking David’s plans for the future to which he responded that he would like to make websites.

When asked how he perceived the makerspace and activities connecting to his Web design future, David articulated that he saw the makerspace connecting to Web design and his future career with regard to “the coding, especially with the [Linux] terminal.”

David and identity. After discussing technology-related plans for the future, David was prompted to articulate his identity or identities. He commented:

> *David is the person that gets people to rethink about certain ideas like based on my school and things that go on in my school. They wouldn’t expect me to be doing the things I do. So I just get them to get rid of that mindset like anybody can do this, that type of thing.*

At the end of the interview, when asked about his five-year plan, David indicated that he hoped to do "something with programming somewhere at the university" and that he had heard there was "a school in Austin that has to do with programming." Next, David was asked if he "feels" like a programmer and at what point he had begun to describe himself as a programmer. He articulates that it began with the beginning of the year when he started learning HTML and JavaScript. The researcher then questioned David as whether he "felt" like a programmer when he was using the drag-and-drop Scratch programming interface. David elaborated:

> *It's like even though some of it was typing I did and the other part was just dragging the pieces together, it still feels like it because you still got something to do something.*

Lastly, in response to observed help-giving and help-seeking at the makerspace, David was questioned whether he had helped others with the programming challenges. David explained that he had helped Osiel in learning how to use the Scratch interface. He then explained it made him feel "good about [him]self" to have helped Osiel.

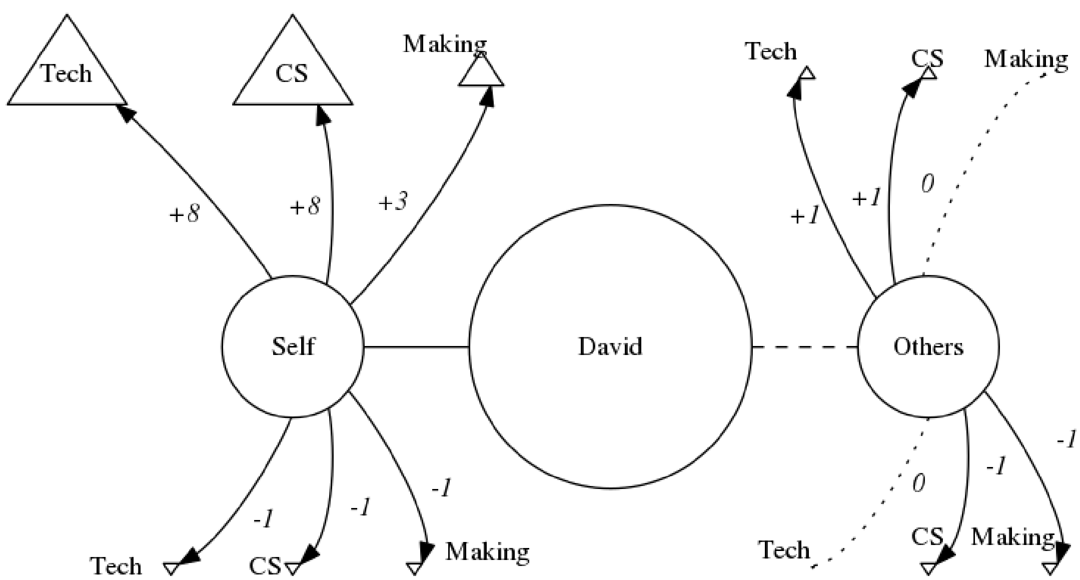

Figure 30. David's post-Camp discriminated interactional history. This diagram illustrates the interactional history discriminated from David's post-camp interview.

David's post-camp discriminated interactional history. David's last interview highlighted more positive interactions with technology and CS (See Figure 30). In the interview David listed relatively frequent positive self-CS, technology, and making interactions (+8, + 8, +3) and few aversive self-CS, technology, and making interactions (-1, -1, -1). Though David's own positive interactions with making were evoked, those of his friends and family were not.

David's Relational Diagrams

David's relational map utilized all the provided identity using only the suggested relationship descriptors. David left early the second weekend, in order to go to work. David did not complete the between weekend relational diagram, owing to schedule difficulties. (He completed the interview standing outside talking to the primary researcher.) The most noticeable changes are: coding as an interest then a "love" relationship; other ethnicities labeled as "understand" and then later "like."

David's Sources of Control

Analysis of David's interview statements highlighted the strength of the environment in positively reinforcing interactions with technology, CS, and making (See Figure 31). More than with other participants, David's family was the next most commonly discerned source of influence, whereby his family's relations and verbal behavior regarding CS, technology, and, especially, making were mostly positive and less averse. By contrast, the discriminated influence of David's peers was only slightly beneficial and a bit aversive regarding CS, technology, and making. David articulated slightly more aversive control with relation to CS, technology, and making. Given the high value of discriminated researcher control (+6), it is especially recommended that all discriminated sources of control and articulated interactional histories be considered relative to the researcher's probable effect as a signal, an S^D, encouraging positive valuations of CS, technology, and making.

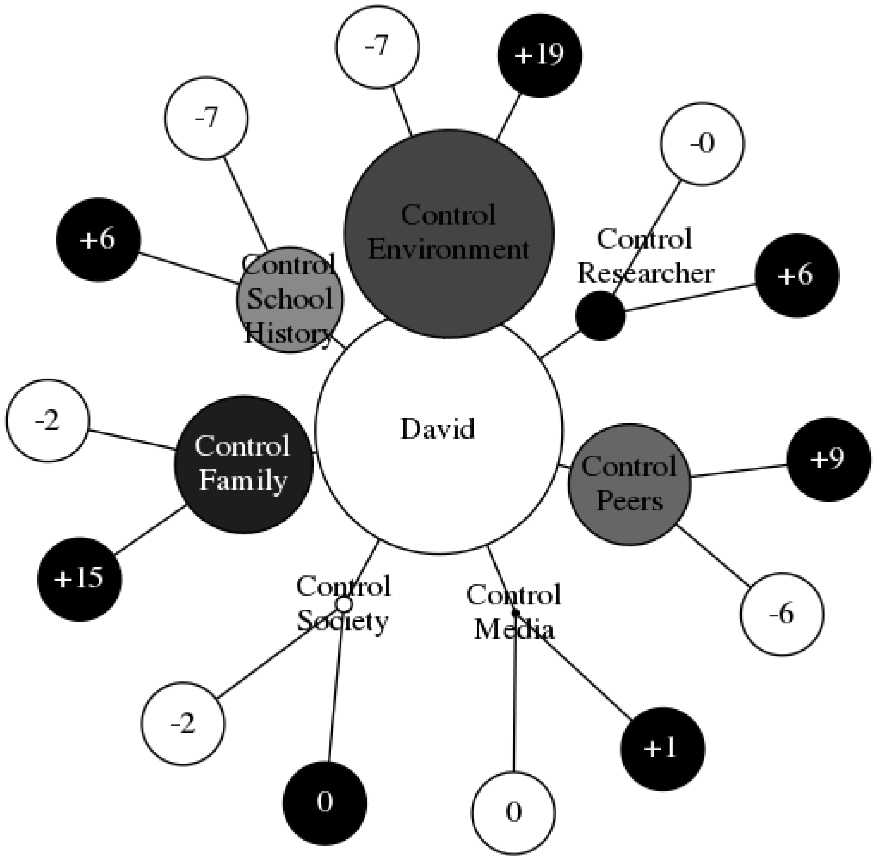

Figure 31. David's sources of control. This diagram illustrates the sources of control influencing David's behavior as discriminated from interviews by the researcher.

Osiel

Osiel Pre-Camp

Before the first makercamp, Osiel indicated that he had not heard of makerspaces or maker activities. Osiel was then first questioned who he perceived to be the kinds of people who create things with computers. He responded that such people were "artistic people and like people who know…how to design stuff and are interested in art and like computers." He was then asked as to whether he was such a person. He replied, "somewhat, like images and stuff like that." In order evoke a more detailed explanation, Osiel was asked in what ways he was not such a person. He responded "like people are not interested in the computers—they don't know how to use them."

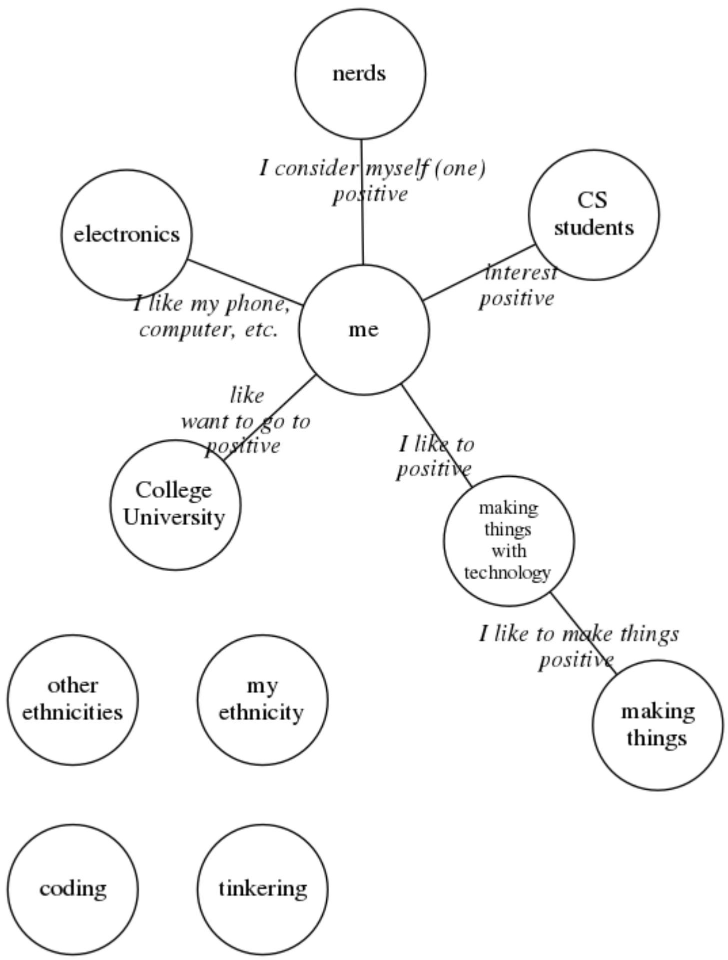

Figure 32. Osiel self-articulated relations pre-camp. This diagram reproduces Osiel's pre-camp self-depiction of his relationships to topics possibly influencing interest in CS and making.

Osiel's pre-makercamp perceptions of programmers. As Osiel had shifted the focus to computer programmers, he was then queried as to what kinds of people were computer programmers. He responded "smart" and indicated that he was not that kind of person, because "programming and stuff and all that technical [stuff]" seemed confusing to him. Osiel was then prompted to describe a stereotypical programmer if possible. He then explained that a programmer is “someone who’s smart, probably straight *A’*s and they’re not only like geeky but they’re like really smart and they have glasses maybe.”

Later Osiel was asked what might lead someone to become a programmer. He posited individuals might take an interest in programming “because they see…television shows like *Criminal Minds* and…when the character does like hacking and stuff” and “so they probably get interested in…the hacking and coding and stuff.” He then indicated that although he had seen the show and it seemed interesting, he did not think he would be able to do that. He clarified that “it takes many years of learning…and [he’s] not good at memorizing.” Osiel then conjectured that someone who programs must be good at memorization “because [of] all the codes and such.”

Delving into Osiel’s interactional history with regard to programming, the researcher prompted Osiel to share his history with computers and programming. Osiel indicated that he had done coding and Web design. He then expounded citing his use of “some HTML and stuff like that” on Tumblr. However, he dismissively noted that the Tumblr interactions primarily involved the copying and pasting of code snippets. The researcher then asked if Osiel thought that programmers might use such an approach. Osiel stated that they probably customized their profiles in such a way but that they code “probably mak[ing] it from scratch instead of using templates.”

Osiel’s relations to making. In an attempt to discriminate Osiel’s relations to making, Osiel was asked how making and creating things with technology related to him and his life. He revealed that he had been using technology more since he had come to the magnet program, that “it’s like more important to make stuff like on the computer,” and that “it’s like increasing [his] artistic views and stuff.” The researcher then queried whether Osiel’s friends used computers to which he responded that "some of them make videos on their phones and stuff." Then he was asked whether he had any friends who were programmers to which he replied "no." Osiel also explained that his friends were not artists, but "people at school that make stuff."

Osiel's community and computers. The researcher also inquired if any of Osiel's family or people in his neighborhood worked with a computer for a living. He indicated "no." The researcher then followed up asking about "people who [did] things with computers." He indicated that possibly someone in his family but he did not think so. In an effort to discriminate potential patterns of reinforcement, the researcher prompted Osiel to describe how his family responded when he told them about making stuff. He indicated, "they don't seem as interested. It's like 'yeah, that's cool.'" Osiel also suggested a lack of response from friends with regard to his art.

The researcher then followed by asking, "So why do you do it?" Osiel then explained:

> *I don't know. I feel like when you create something on a computer, you feel like excitement. I guess like you're happy that you actually [made something] cool on a computer instead of just making something on paper [that's] not as interesting.*

In response to Osiel's implication that making on the computer was better than on paper, the researcher encouraged Osiel to explain why making on the computer was better than making on paper. Osiel replied, "Well, everybody can make things on paper," and elaborated that "all that stuff on a computer is more…complicated." He concluded, "It just looks better on the computer." Later at the end of the interview, Osiel was asked to give specific examples of what he had made with computers and technology. He listed making movies and using Photoshop on images.

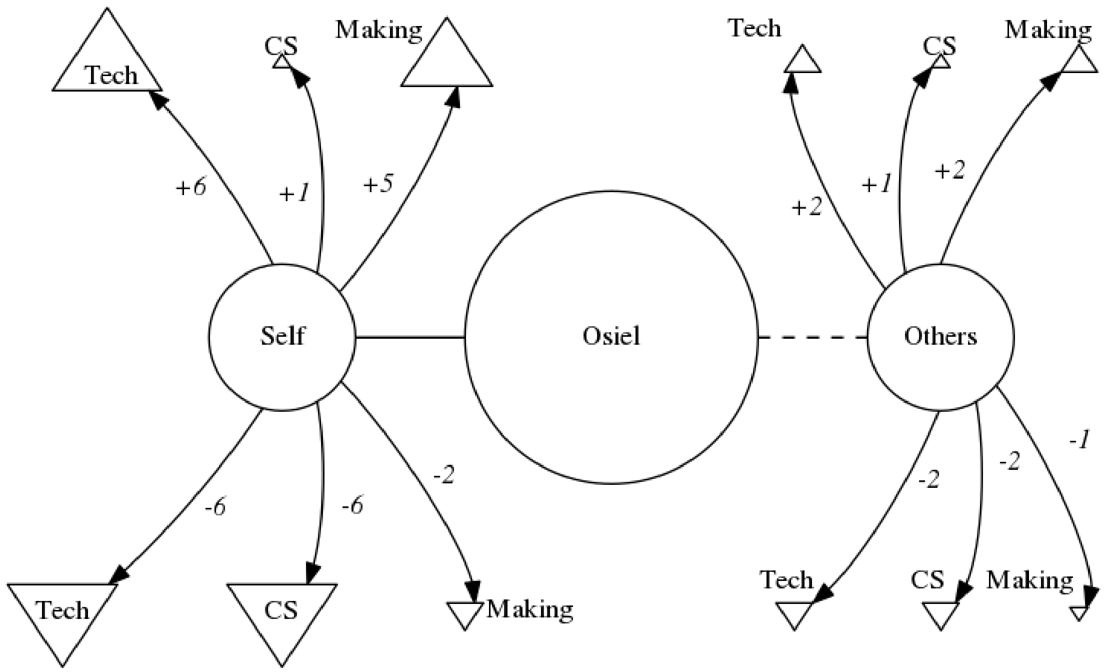

Figure 33. Osiel's pre-camp interactional history. This diagram illustrates the interactional history discriminated in Osiel's pre-camp interview.

Osiel's pre-camp discriminated interactional history. Osiel's pre-camp interview revealed relatively frequent positive interactions with technology and making (+6, +4) and more frequent aversive experiences with technology, CS, and making (-6, -6, -2; See Figure 33). The pre-camp interview suggested that Osiel's own and others' interactions with technology were equally reinforcing and averse (See Figure 33). His descriptions indicated that his own and others' interactions with making were more reinforcing than aversive. He articulated his experiences with CS as being pronouncedly more averse (-6) than positive (+1).

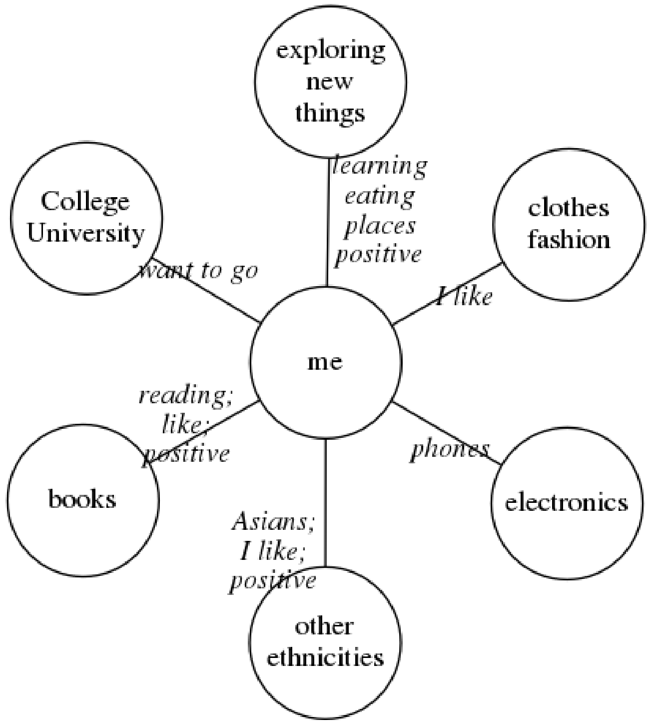

Figure 34. Osiel's self-articulated relations between camp weekends. This diagram reproduces Osiel's labeling of his relationships to topics possibly influencing interest in CS and making.

Osiel between Makercamp Weekends

In the between-camp interview, Osiel was first questioned about his perceptions of the makercamp. He clarified, "It was fun actually." He then elaborated:

> *Like I—I didn't expect it to be fun. I expected it to be a lot of work. It's not much like coding and like typing and it will be really complicated but it was easier than I thought.*

Osiel's description of the makercamp. Osiel was prompted to describe what he thought about the actual space. He noted that on the outside it is "kind of sketchy" but that he "thought the building was nice" recalling a different room at each turn. He was then asked if it seemed more "informal" than he expected, to which he indicated "a little bit, not really though." The researcher then followed up by asking Osiel how the makerspace compared to places "like schools or libraries." He observed that he had expected "rows of desks" but that there were "more like groups of desks" for "mostly like pairing up." He then described the space as "homely" which he then corrected, after researcher prompting, to "homey."

Osiel and social stimuli. The researcher then continued soliciting details about the social environment of the makerspace and the makercamp. Osiel indicated that he had spoken with adult participants from the makercamp; however, he stated that he had not spoken with the other adults at the makerspace, even during the tour.

Later the researcher queried whether Osiel might return to the space; he replied "possibly yeah." Osiel indicated uncertainty about when and whether the makerspace was open to the public. Then, in order to ascertain the potential role of social reinforcement of maker activities, Osiel was questioned as to what he had told his friends and family about the makerspace. He stated that he did not think he had told anybody about the camp.

Osiel and physical stimuli. During the interview, Osiel elaborated that he had not used the "free time" to explore the space, but, rather, had stayed to work with the Raspberry Pi. He also noted that he "wish[ed he] could have looked at the laser cutter" as it interested him. Later after Osiel was asked if he would return to the makerspace, the researcher then offered to give Osiel acrylic for the laser cutter, to which Osiel responded that he "would probably do that."

Osiel and programming. When asked about the makercamp activities and whether they were "too challenging," Osiel indicated that the "Morse code" challenge, spelling his name out in dots and dashes with an LED and possibly Piezo, did "confuse" him. He also indicated some confusion with the switch commands for the PiBrella and Scratch GPIO.

Osiel and Maker Plans. The researcher inquired if there was anything that Osiel would like to make; Osiel indicated that he was unsure. When pressed about whether he would like to make something with plastic, Osiel indicated that he was “unsure” as he had “never thought about it.” Following up as to the role of the environment, the researcher asked Osiel if the makerspace had “inspired” him to make anything different or whether he might make anything different as a result. He responded that by engaging in activities such as going to the makerspace he could make and “explore new things.” The researcher followed up asking if that was something Osiel was likely to do. He replied “sometimes, yeah” and then that he had done things like exploring before, which he compared to visiting new churches and trying new drinks at Starbucks.

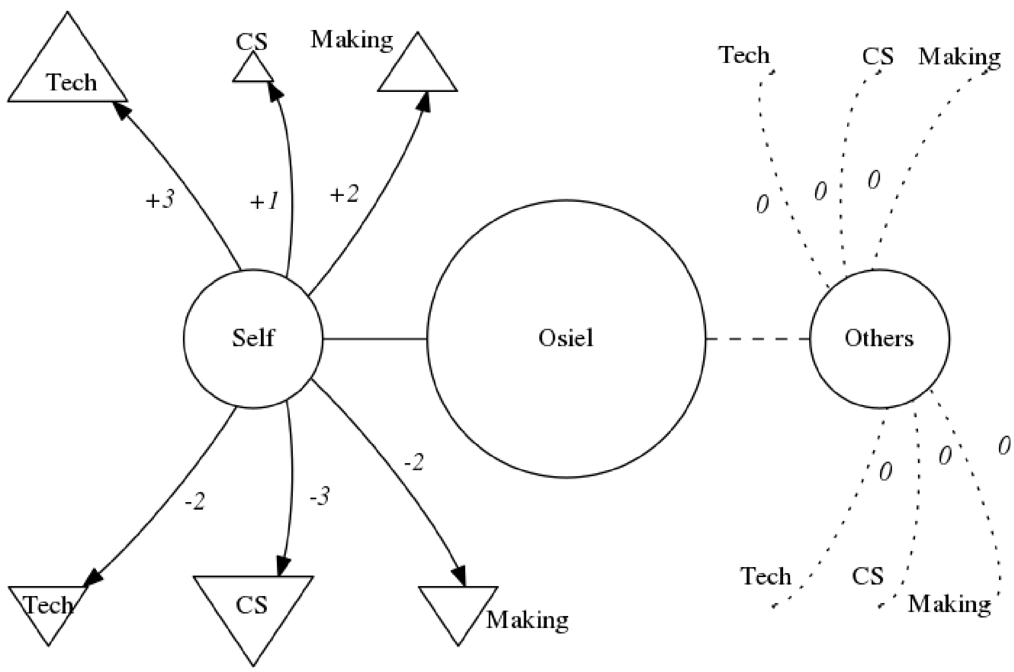

Figure 35. Osiel’s between-camp discriminated interactional history. This diagram illustrates the interactional history discriminated in Osiel’s between-camp interview.

Osiel’s between-camp discriminated interactional history. Osiel’s between-camp interview presents a personal history of fewer positive interactions with technology, CS, and making (+3, +1, +2) than discriminated aversive experiences (-2, -3, -2; See Figure 35). Similar to Osiel’s first interview, his CS interactions were articulated as more aversive, though to a lesser extent. The ratio of positive to aversive making histories was less weighted to reinforcing, being discriminated as equally aversive and reinforcing (-2, +2). No positive or averse interactions of Osiel's peer or family to technology, CS, or making were discerned.

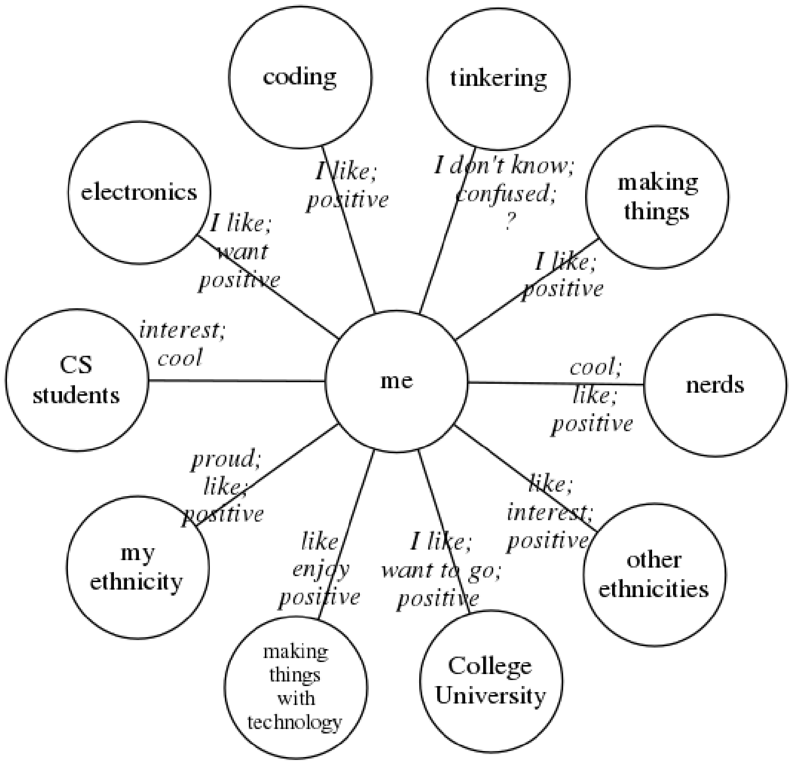

Figure 36. Osiel's self-articulated relations post-camp. This diagram reproduces Osiel's post-camp self-labeling of his relationships to topics possibly influencing interest in CS and making.

Osiel after the Makercamp

Osiel did not attend the second weekend of camp as he was out of state on vacation. He noted that he had not attended the second day of the first weekend because when he woke up, "nobody [was] there." For longitudinality and participant comparison purposes, the researcher began by prompting Osiel to describe what he could recall from his first and only day at the makercamp. Osiel first noted that he recalled being at the makercamp "right on time" or "a little bit late." He then recalled having a microphone clipped onto his shirt and "start[ed] learning about Raspberry Pi's and…the Pibrella and stuff."

Osiel and code. The researcher then asked Osiel about his thoughts on drag-and-drop programming. Osiel noted that "it was easier," and observed "if I [had gone] the second day, it would [have been] harder because you all did code that day" to which the researcher inadvertently noted that "[they hadn't done] code the second day." After which, Osiel continued noting that "it was pretty easy" and was reminiscent of the Code.org activities. The researcher followed up by asking Osiel his perceptions of such coding, whereby Osiel responded that "it was easy, or easier than like, regular, like having to type it out." The researcher then queried if drag-and-drop was "coding" or "programming." To which Osiel replied that "yeah [it's coding], but not like from scratch," noting that "it's just like already done for you, so it's like easy for you to understand how to do it."

Although Osiel did not elaborate on interactions with the programming environment, Scratch GPIO, he provided multiple perceptions of the "Morse code" challenge, a challenge whereby students were provided with a Morse code alphabet and asked to program their name with LEDs, Piezos, or both. Osiel mentioned that he was "confused" because of the "lines and dots." He indicated that he did not know if "the lines had to also be spaced out [with] a pause." He then queried aloud "or is it just long and it was just like short, short, short, without any spaces between." The researcher followed up by asking if the task was too challenging, to which Osiel responded "not really." Elaborating on his coding experience, Osiel noted that he had not explored the space during free time but had stayed behind to figure out the task.

Osiel's descriptions of school and makerspaces. Building on the school discussion, the researcher queried Osiel about the differences between activities at the makerspace and school. Osiel noted that the makerspace was more challenging because school was "step by step" and the makerspace was "like they teach you somewhat" and then "just…go work on it." And, unlike school, he “actually asked questions.” He then noted that he “[didn’t] really ask that many questions” so he was learning if [he] could learn it on [his] own” and that it was, consequently, “more challenging to [him] like that.”

Osiel’s social contingencies. In order to ascertain social contingencies likely to affect Osiel, the researcher asked Osiel what he had told friends and family about the makerspace. Osiel indicated that “they” asked him what he had done that day, and that he had responded that “we just like messed with this thing like [a] computer, [the] Raspberry Pi” that one “hook[ed] up wires” to and dragged and dropped “little icons” to “make it do stuff.” The researcher then queried as to Osiel’s family’s responses to which Osiel noted that “they were like not that interested, like usual” and that they had responded, “Oh yeah, OK, that’s cool.”

Osiel was then asked if he had any plans to return to the makerspace. He indicated “maybe” and that it depended if he was “invited” or if there was an event then he would go. Osiel then responded to the researcher that he, Osiel, had not signed up for the makerspace mailing list.

Returning to the theme of family, Osiel was asked later[15] in the interview what was important to him in his life. Osiel replied “friends, family” and elaborated with “things that make you happy.” Probing the reinforcing quality of social contingencies, the researcher then asked Osiel “How do friends make you happy?” Osiel explained, “[Friends] are there when your family isn’t.” Subsequently, he notes, “but your friends…can be there a lot of the time, but not always be there when you wake up.” He clarified that “in a way, you’re more comfortable with your family” but “you could tell your friends more things than you can tell your family sometimes.”

[15] Approximately minute 16 of 26

Osiel then draws a connection between family always being there and judgement, stating "[be]cause your family is always there and maybe they'll…judge you like that."

In attempts at clarification, the researcher then prompted Osiel to explain why he likes talking to his family if they are more judgmental than his friends. Osiel responded that it is because "they're your blood relatives" which means that "they'll always be with you and they will like die for you."

Concluding the interview,[16] Osiel was asked how he felt working with David and the others. Osiel explained that "at first" he thought "oh no." He explained that this was because he was "not a very social person." He then suggested that, with regard to social skills and talking to others, he was "lower than average, way lower than average." Osiel also indicated that the encounter with David was more awkward than meeting someone new because he had known David since sixth grade but had not talked to him. He then indicated that he had been more comfortable communicating with David during the makercamp.

Osiel and identity. In the post-camp interview, the researcher asked Osiel to explicitly articulate his identity. He responded that he was "not afraid of anybody" and continued by observing, "When you grow up, [you] just do what you want and don't be afraid of what anybody else is going to say about you." The researcher then queried what labels others might place on Osiel, to which Osiel responded indicating "cuss words" and followed up with "homophobic words" and "hateful words."

Osiel's discriminated stereotype effects. The researcher then asked, "What about academic words?" Osiel then explained that he "would say [he] wants to be a surgeon." However, he notes that his friend asserts that he will "never be a surgeon" because he does not

[16] Minute 24 of 26

"get the best grades." Osiel then indicated that he had responded to such assertions by contradicting with "I don't care what you think 'cause I know what I want to do in life." He explains, "If he just changed [his] mind about being a surgeon, then [he's] still going to do something…that's very smart." He continues, noting that he "think[s he's] smart" but that "some people don't think" that he is smart because "sometimes [he doesn't] work out [his] problems with [his] studies" or "do [his]" homework a lot." He then shares that his "grades aren't the best" and that he "had barely passed."

The researcher then asked if "nerd" could be a label for Osiel, which Osiel affirmed, as he was not "gang-y." He then described that his magnet program could be "considered nerdy" as it is so "technical." Expounding by indicating that the program is "like computers, how to do coding, and all that" and concluding "but I think it's fun", where "but" suggests that Osiel's relation to nerds depends on the framing of the relationship (See Figure 37).

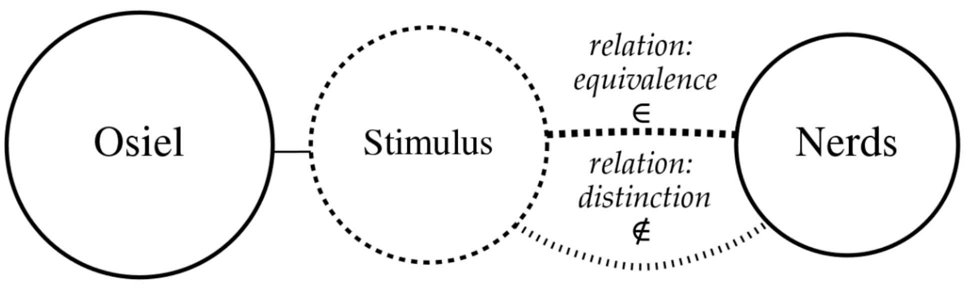

Figure 37. Osiel's stimulus dependent relation to nerds. This diagram illustrates how Osiel's relationship to nerds in contextually dependent — a relationship of sameness or difference depending on the situation.

Later in the interview, Osiel was asked whether ethnicity related to being a nerd. Specifically, he was asked "Does ethnicity determine who's a nerd or not? Or gender?" Osiel then replied "sometimes…but not really" indicating that:

It's more like stereotypical, like, most likely people will say Asians are the smart ones. …and sometimes, they will say like Indians are the smart ones and then some people will say that Mexicans are those, uh, or Latinos, I think, are the dumb ones. And like it just goes back and forth.

Osiel and CS. Following the nerd question, the researcher queried Osiel regarding his relationship to "computer programmer" or "computer scientist." Osiel then responded that "if anything goes bad in life," for example, if he "[didn't] like medical stuff anymore" or "broke [his] leg or something" then he would "probably go into computer programming."

Osiel and makers. Transitioning from the question of CS identity, the researcher asked Osiel how he relates to maker culture and whether he was a maker. Osiel affirmed that he was a maker and explained that there are "different types of makers." He then explained that "it's like I could be a maker physically by making those light cut-outs that they do in the makerspace." He clarified that there are different types of makers "like programming makers or video editing stuff." He then expounded that he would be a "making videos" type of maker.

At the end of the interview, Osiel explicitly clarified that he perceived "not such a strong relationship" between himself, computer science, and making. He then concluded the interview by predicting that he will not be Osiel the surgeon in future, as that will take too much schooling, but rather that he will be Osiel in the medical field.

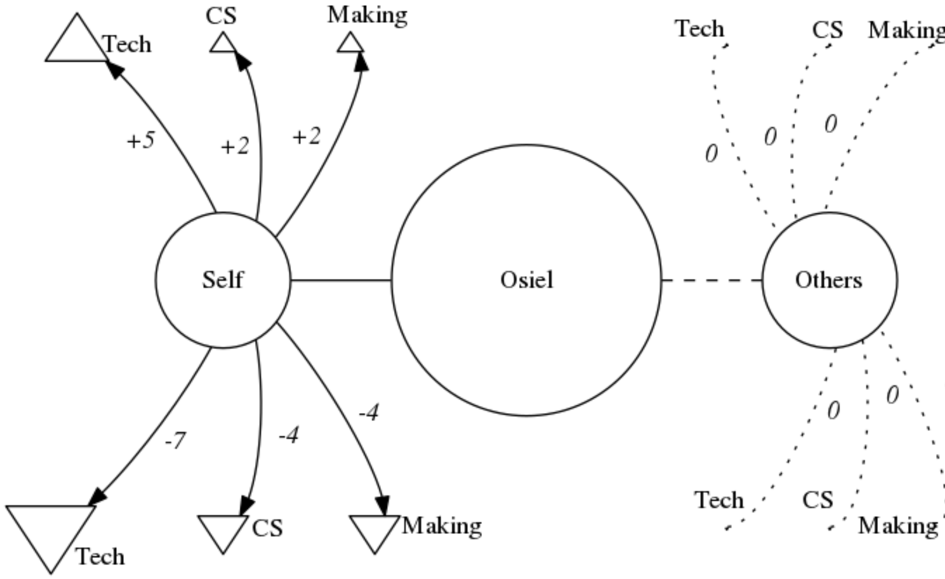

Figure 38. Osiel's post-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Osiel's post-camp interview

Osiel's post-camp discriminated interactional history. Although Osiel described positive interactions with CS, technology, and making, in his final interview (+11), he recalled more aversive experiences (-15; See Figure 38). He did not verbally articulate others' relationships to technology, CS, and making. It is perhaps noteworthy that Osiel's descriptions of others' connections to CS, technology, include no interactions discernable as positive or averse after the first weekend of camp. This lack of articulation may be the result of extinction arising from Osiel not having been reinforced or punished by his family's verbal behavior regarding the first weekend of makercamp.

Osiel's Self-Depicted Relationships

Osiel's responses followed an atypical route. In his first and last diagrams, he restricted his responses to suggested relationship elements; however, in his in-between diagram, three of the six listed elements were not among those suggested, i.e., "exploring new things," "clothes/fashion," and "books." The in-between diagram also included the "other ethnicities" element with the label "Asians, I like, positive." His last diagram included all of the recommended elements. Four additional recommended categories were included beyond those depicted in the first diagram. Osiel's self-depicted relationships include: coding ("I like, positive"), tinkering ("I don't know, confused"), my ethnicity ("proud, like, positive"), and other ethnicities ("like, interest, positive").

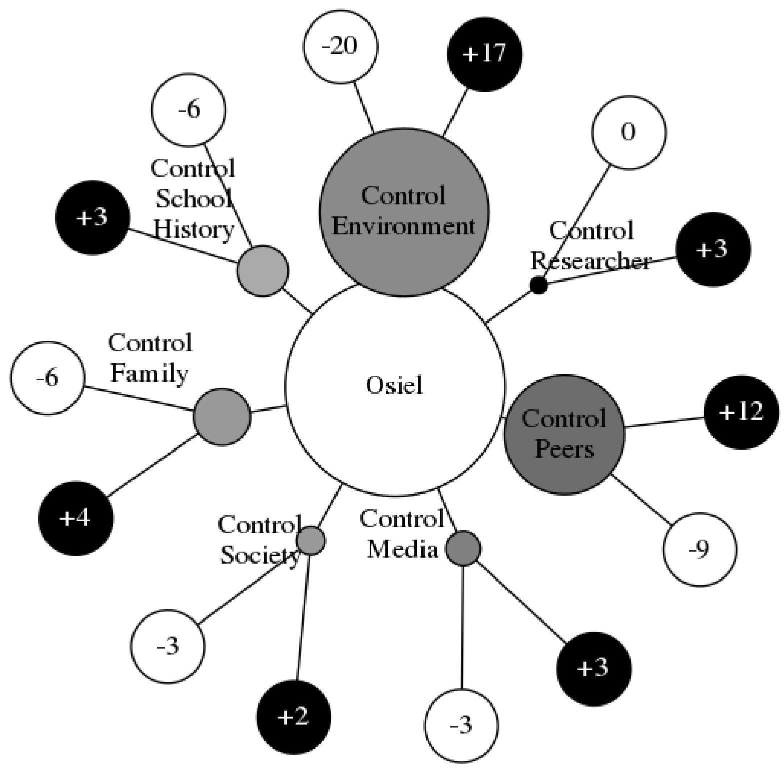

Figure 39. Osiel's sources of control. This diagram illustrates the sources of control influencing Osiel's behavior as discriminated from interviews.

Osiel's Sources of Control

The factors influencing Osiel suggest the interconnectedness of factors influencing behavior. Osiel's responses suggested that more than a one-to-one correspondence of past events affecting current interest, which could be illustrated as a linear function mapping current engagement to past experiences, that converging interactional histories may have multiplicative effects on the saliency of stimuli and consequent emission of behaviors, which could be illustrated as a much steeper line, or even as an exponential curve (cf. C. Hull, 1943).

Osiel articulated many external sources of control; both aversive and positive (See Figure 39). Clearly discernible as a source of control, Osiel's description of his family suggested more averse control of interactions with technology, CS, and making. Similarly, school history and the environment seemed to exert more aversive control. Though the researcher's presence most likely served as a signal, an S^D, for positive statements regarding CS, technology, and making, any ameliorating effects regardless of how slight or strong, did not suffice to evoke a higher ratio of positive to aversive statements.

Sara

Sara Pre-Camp

Sara was unable to attend an interview session before the camp began. Consequently, a replacement interview was conducted immediately following the first day of camp. In this initial interview, Sara indicated that she had not known what a makerspace was before attending one. She defined a maker as someone who "could be you or me," namely, someone who "makes things." When asked to describe what a maker makes, Sara responded "like anything that they want." She elaborated, "like they make things with programs or they make video games."

Sara was then asked about "the kinds of people who create things with computers." She explained that "video game designers" and "programmers" are those types of people—a type of person she "want[s] to be also." Then, in contrast to other participants, Sara indicated that she had had "computer science," referring to her pre-AP CS class. Consequently, she was then questioned about her experience with computer science. To which she responded:

It's like at first it was hard but then as I like got help and I like moved on and everything in class and I learned more and more. The stuff I learned I would be always like I brought together and we would do some projects and I would struggle because I didn't know what I was doing, but now I know what I'm doing and everything and now I get most of what I was taught, well I can do it more easily.

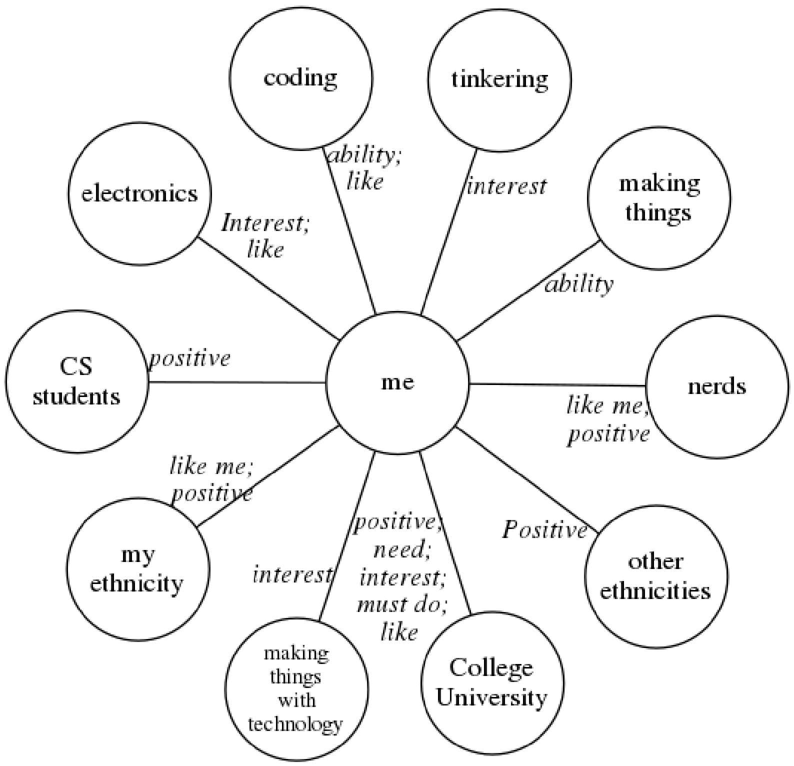

Figure 40. Sara's self-articulated relations pre-camp[17]. This diagram reproduces Sara's labeling of her relationships to topics possibly influencing interest in CS and making.

Sara and CS. Sara explained that she took computer science because she "like[d] playing video games" and "want[ed] to become a video game designer." She clarified that she had not

[17] Owing to Sara's scheduling conflicts, the self-making map and first interview were collected at the end of the first day of makercamp.

known what a computer scientist was except that they "were like people who were able to…make the programs that [she] use[d] every day." The researcher then followed up asking if Sara knew any such people. She explained that her mother used the program "PeopleSoft" but that she did "not know what that is" only that "it is a program she has to use every day."

Sara and Friends. Sara was then asked what relationships her friends have to making. Sara explained that one of her friends "makes videos" for school and "does lots of animation." She then added, "He does a lot of coding too" and that "a lot of [her] friends are into computer science because they like to code and create things." Sara also indicated that she had friends who took CS before she signed up for it.

Sara and CS reinforcement. When questioned about her mother's responses to her coding, Sara stated that her mother "is amazed" Sara can code. Sara then elaborates that her mother does not "know that many people that do this kind of thing." Similarly, Sara indicated that when she shows her friends what she has made "they are amazed."

Sara was then asked her perceptions of "what makes people want to study computers and programming." In response, Sara explains that she "got inspired by video games." The researcher then asked Sara to elaborate on her past interactions with technology. She recalled using Photoshop, putting faces onto other faces, and sharing them online. She then detailed progressing to an animation program. Describing her progression, she noted, "it's very hard to do, but as I move on and I get more programs and more and more, I'm able to expand what I like to do."

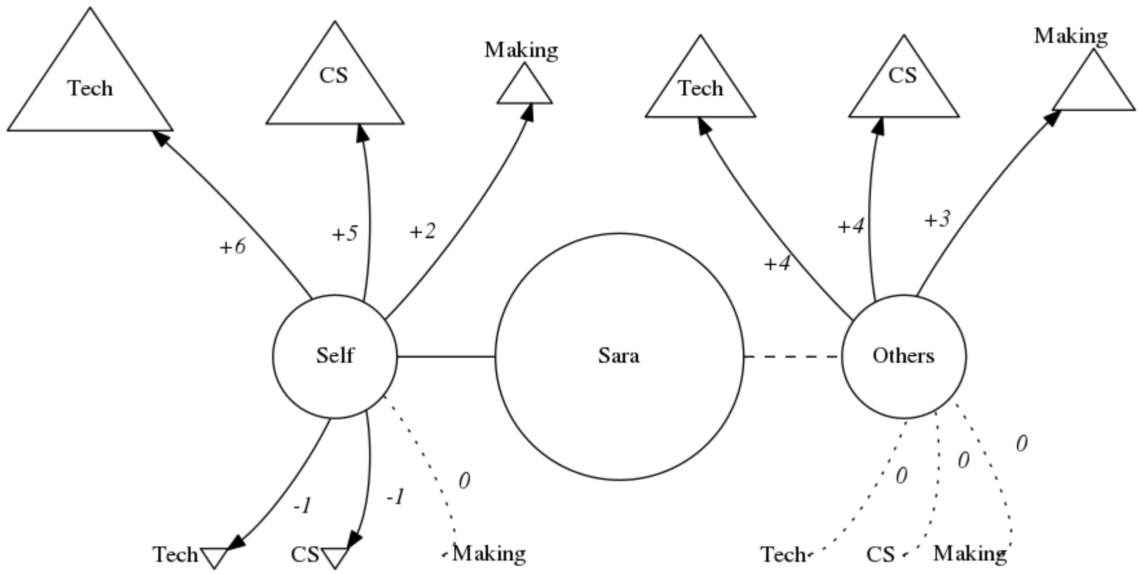

Figure 41. Sara's pre-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Sara's pre-camp interview.

Sara's pre-camp discriminated interactional history. Sara's first interview presented a history of many positive interactions with technology, CS, and making for Sara (+6, +5, +2) as well as for her friends and family (+4, +4, +3; See Figure 41). It was problematic that Sara's first interview was held in the makerspace, which may have increased Sara's likelihood to discriminate more positive interactions with technology, CS, and making. However, considering Sara's later interview and makercamp statements, it was generally more common for Sara to recall positive experiences. However, it is unclear whether Sara's personal experiences or those identified by others most affected her articulation and valuations of CS, technology, and making, as Sara's positive discriminations seem to share a reciprocating effect with those interactions she identifies others as having.

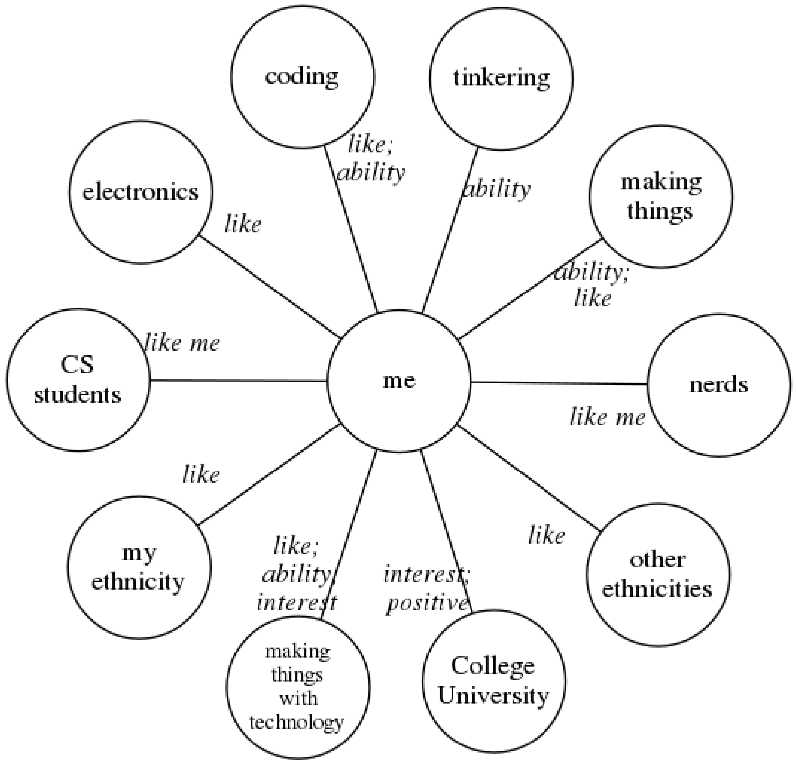

Figure 42. Sara's self-articulated relations between camp weekends. This diagram reproduces Sara's between camp labeling of her relationships to topics possibly influencing interest in CS and making.

Sara between Makercamp Weekends

Between camp weekends, Sara was asked about her experience at the makerspace. She indicated that it was "fun" and that when she was "on break" she had "learned a lot more" about makerspaces. Namely, she noted that she had talked to makerspace members during the break. She had talked with an adult makerspace member who was also attending the camp. Sara elaborated that he talked about "the walls," then "afterwards," they discussed "what everyone does" at the makerspace. She then clarified that he "goes there all the time" and "just like make[s] things and everything."

Next, Sara stated that she "learned more about the laser cutter" and that it was "just really fascinating." She also stated that she "like[d] the 3-D program." She then continued her narrative explaining that one of the members approached her and admonished that “she must also contribute to helping keep the makerspace clean” and that she therefore “helped with the trash and everything, but still it was fun.”

Sara’s prediction of return to the makerspace. Sara was asked if she would return to a makerspace, which she affirmed, stating “yes, [she] would.” She clarified that she liked how “they” told her how to make things and that there were “a lot of tools” that she did not have. First, she described the laser cutter, and then she described the screws, explaining “they had lots of different screws” and that in her house “it’s hard to find screws.” Then Sara posited that given the plethora of tools at the space, one could “just build out of scratch” and that is “really amazing.”

The researcher then questioned Sara if she were a maker, which she then confirmed. In order to unearth further examples of social contingencies influencing Sara’s behavior, the researcher queried what she had told her friends about the makerspace. Sara recounted that she “told them it was really cool and everything.” She even noted that she “had taken a picture of how it looked” and “had sent it to them,” whereby “they thought it was really cool too.” She also mentioned having sent the videos to her mother as well. Sara noted, “They were really amazed by it.”

In attempts to discern the sources of reinforcement and discrimination within Sara’s verbal community, the researcher probed, “What were they amazed by?” Sara explicated that her verbal community was amazed by “the things” at the makerspace, such as the laser cutter. Sara then explained that she had expected a “little thing” but instead discovered “a giant box.” She clarified that it was “more than what [she] was really expecting.” Moreover, Sara elaborated that her mother had “never seen any of that stuff” and that her mother’s response was “Wow, I didn’t know there was something like that.”

Continuing the investigation of interactions among Sara and her mother with response to the makerspace, Sara was asked if her mother “might want to come and use the tools.” Sara replied that her mother was “kind of like this artsy person” and that her mother had a sewing machine, glue guns, and makes costumes. Sara indicated however that her mother mother’s visit would depend on her brother getting older, explaining, “If [my little brother] gets older, she just might want to go and actually do that” (cf. Figure 43).

Sara’s engagement with the makerspace. Sara was asked to articulate whether the activities at the makerspace were engaging. Sara replied, “Yes, they were, because we each had a partner.” She indicated that the participants “were actually engaged in social and physical with the computer also [sic].” She then clarified that participants “were engaging in two activities all at once,” namely, “talking with…partners about what to do” and “creat[ing] what [they] were doing.”

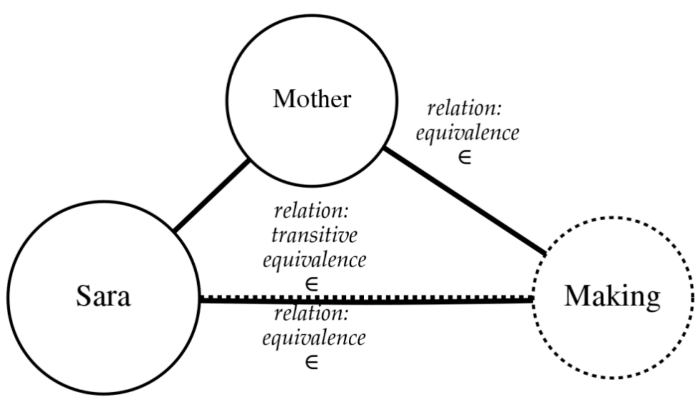

Figure 43. Sara’s direct and derived relation to making. This diagram illustrates Sara’s direct relation to making and her derived relation to making owing to the relationship to her mother.

Sara's recollected social contingencies at the makerspace. In order to assess Sara's social interactions within the makerspace, she was questioned about with whom she spoke. She once again noted one of the makers from the makercamp. She also noted another maker who had attended the camp who had showed her a videogame cabinet that he had restored using the RetroPi, a Raspberry Pi distribution for playing older video games. Further, she recalled talking to a high school age female makercamp attendee, who was not a participant in the study. Additionally, Sara recollected having talked to the member who had asked her to take out the trash. After which, she recounted asking him about the project he was working on, a "Be More" (abbreviated as BMO and pronounced *bee-mo*), a Raspberry Pi emulator modeled after a character from the cartoon *Adventure Time*.

Sara's discrimination of makerspace and other environments. Sara was asked to compare the makerspace with school, libraries, and other learning environments. Sara replied that the makerspace was "much more fun" because "it is something that really interests" her, namely, making projects. Then, Sara was asked if others would be interested in knowing about the makerspace. She explained that people "who like to create things and stuff" would be interested in the makerspace.

As with all interviews, the researcher concluded by asking Sara if she had further questions. Again, in contrast to other participants, Sara had a question. She asked if it would be possible to bring supplies to the makerspace. She questioned whether she might be able to convert her 2-D drawings into a 3-D model, similar to the 3-D laser-cut dinosaur skeleton on display next to the laser cutter. She repeated a conversation with another makerspace member about the process necessary for such a conversion. Next, she made plans with the researcher to acquire and learn the necessary software. In finishing the interview, she detailed how her room would not have the necessary space for her planned project and the necessary papier-mâché.

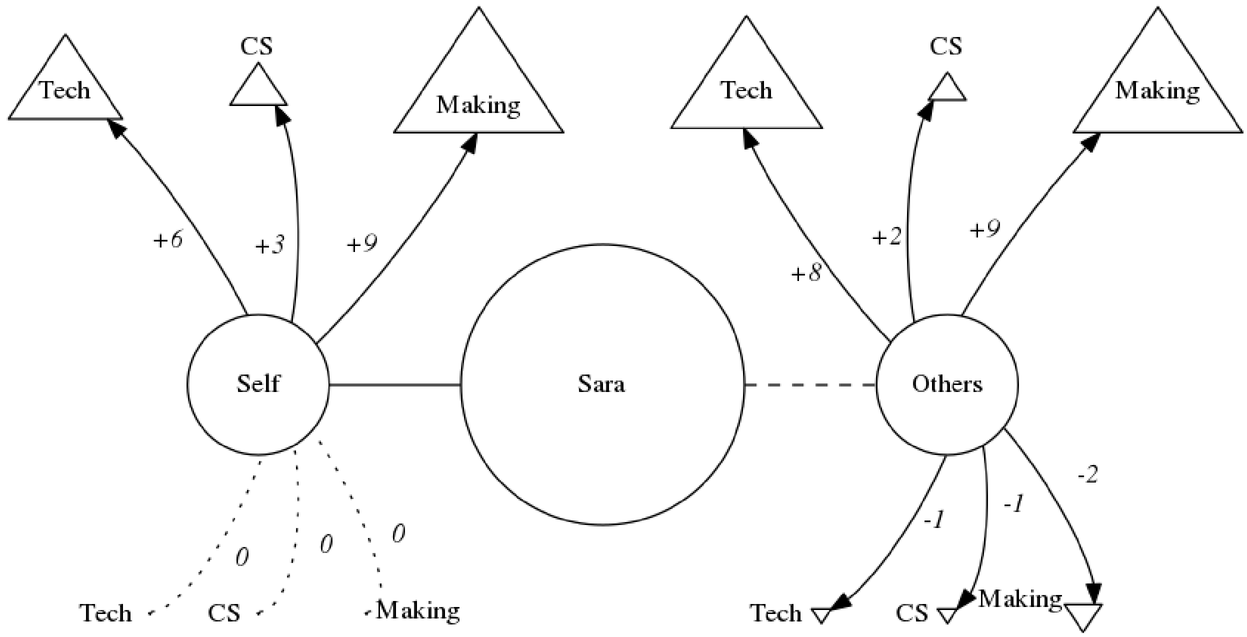

Figure 44. Sara’s between-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Sara’s between-camp interview.

Sara’s between-camp discriminated interactional history. Again in the between-camp interview, Sara articulated many positive interactions with technology, CS, and making for herself (+6, +3, +9) as well as for her friends and family (+8, +2, +9; See Figure 44). She articulated no aversive interactions with technology, CS, and making for herself. Technology and making were the focus of many of her discriminations. The increased salience of technology and making, which were abundantly present at the makercamp, provides an interesting contrast to CS, which was the primary focus of the makercamp lessons and activities. Likely, the structure of the interview may have contributed to the frequency of Sara’s discriminations, but the semi-structured nature of the interview was intentional to allow for and highlight variances in participants’ emission of VB.

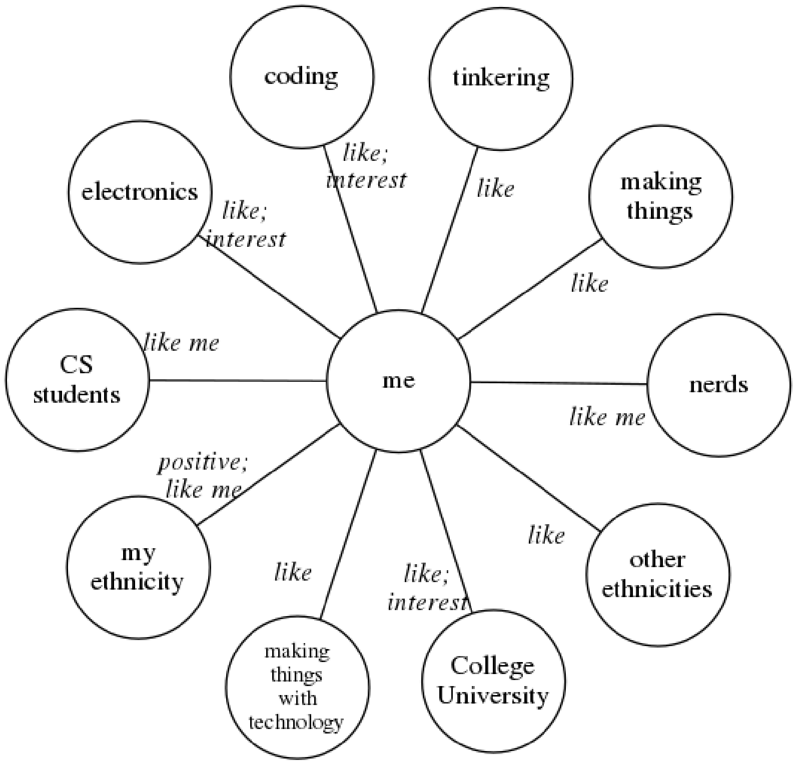

Figure 45. Sara’s self-articulated relations post-camp. This diagram reproduces Sara’s post camp labeling of her relationships to topics possibly influencing interest in CS and making.

Sara after the Makercamp

To begin the post-camp interview, the researcher queried Sara why she had attended every day of the camp. She indicated that it was “because [she] was really interested in all that stuff” that she was “learning about” at the makercamp. She then detailed that her interest was “because it deals with a lot of like programming and technology.” She further divulged that the makercamp and its technology was something she had “never heard of” and therefore she “was interested in learning more.” The researcher then observed that Sara had come for all four days and had made her dinosaur. Sara clarified that she was still in the process of making the dinosaur and that her mother was “going to get the fish wire.”

Sara’s identification as a maker. Next, Sara was asked if she was a maker. She affirmed that she was a maker and had known she was a maker “ever since [she]…learned what makers are," and she "learned [she] was a maker the whole time." The researcher asked Sara if others at the camp had then identified as makers. Sara indicated that they had decided they were makers "because a lot of them said that they made things…like they either make programs, make things with programs, or…everything else."

Sara's perception of programming environments. Sara was then asked her perception of programing environments. She explained that "actually…between Scratch and Python [she] like[d] Python more." She expounded, "Scratch is just like point and drag, just click and drag, click and drag… You're limited to what you can use and I don't like that."

The researcher queried Sara regarding her prior programming history with Java. Sara explained that Java was more "typing out the whole code." Then when Sara was asked whether and why others perceived Scratch as real code, she responded that "honestly" she did not know. When asked if Scratch was "real programming," she replied "sort of and sort of not." She then added that Scratch seemed "like a kid version" and that it was "basic stuff really."

Later in the interview, the discussion returned to differences between Python and Scratch. The researcher queried Sara about the level of challenge. Sara replied noting that "parts like the spacing" were difficult and that she settled on using tab rather than spaces. She also indicated that she may have had an advantage as she had some prior programming experience. She described that she had inferred this by observing that she "would get it before some people" and would then "help others to get it." The researcher then asked "How did that feel?" Sara expressed that "it felt like [she] was knowledgeable."

Following initial questioning about Scratch and Python, the researcher asked Sara if she planned to study CS in the future, to which she replied, "yes…because I like this stuff and I would like to learn even more than I know already." The researcher then followed up by asking how Sara was doing in school, to which she responded that she had “failed the second semester of computer science.” She then explained that she planned to “keep going.”

Similarly, after the second Scratch and Python discussion, the researcher asked Sara if she planned on returning to the makerspace. She initially responded “yes” and then qualified her statement stating, “Well, I feel like I will but I just don’t know.” She then explained that she was “kind of busy.” The researcher then queried about the Raspberry Pi that Sara had taken home from the Makercamp. She indicated that she had looked at RetroPi, an operating system for playing older video games on the Raspberry Pi, but had not had “any luck.” The researcher then asked if she had installed the disk image, which is the primary software requirement to setting up a Raspberry Pi, and she was unfamiliar with the term. Also, Sara indicated that she did not know that the makerspace had a mailing list. The researcher then asked if Sara had “played around with any of the other stuff.” She responded that she had got the lights to go again but that she only had one button whereas “*they* had got eight buttons so [she] just kept pressing it and *G* just kept popping up but that’s it.” Her response seemed more descriptive of the in-class activity than likely Raspberry Pi use outside of class.

Sara’s articulated identities. When asked to describe her identity, Sara explained that she was “someone who likes to create things.” She then substantiated her assertion by listing her creative endeavors including using an animation program, programming, and creating things out of junk. She then summed up her assertion, stating “it’s mostly dragons” and that she would like to convert from 2-D to 3-D.

Sara and the dinosaur. Indeed, Sara soon dedicated much of her time at the makerspace to developing her own dinosaur. She confided that she “felt happy” that something that she liked “came into 3-D,” observing that she had her “own little Spinosaurus.” Sara elaborated that while making her Spinosaurus, “after so many tries, [she] gave up.” Sara predicted that “Someday, I think I’ll be able to. If I try hard enough and learn more about Autodesk, like that guy. He knew a lot and I want to be able…I didn’t know you could do all that stuff.” The researcher then queried, “So, you’ve been working with Autodesk?” Sara responded with “yes, and I failed completely.” The researcher countered, “You didn’t fail completely; you made a dinosaur.” Sara replied, “Well, true, I made a dinosaur but it took time for that one, that dinosaur.”

Sara’s social contingencies. Concluding the post-camp interview, the researcher asked Sara about whom she had spoken with at the makercamp. The researcher confirmed that Sara had spoken with three of the makerspace regulars; Sara agreed without elaboration or mentioning other makerspace adults. The researcher polled about the two high school girls from Sara’s program, to which Sara volunteered “because they [were] her friends.” Similarly, without specific prompting, Sara mentioned that she had spoken with another high school–age girl who was not part of her school magnet program. Sara elaborated that this other girl stayed and helped with the Spinosaurus. When asked, Sara explained that it was fun to work with others and that it had helped with her dinosaur project. She concluded by noting, “Yes, because not everything can be done alone.”

Sara’s post-camp discriminated interactional history. Similar to prior interviews, Sara described positive interactions with technology (+8), making (+8), and to a lesser extent CS (+4; cf. Figure 46). She did not identify as many positive interactions of others with technology, CS, and making. She did identify more aversive interactions with technology and CS for herself (-2, -3) and others (-1, -1).

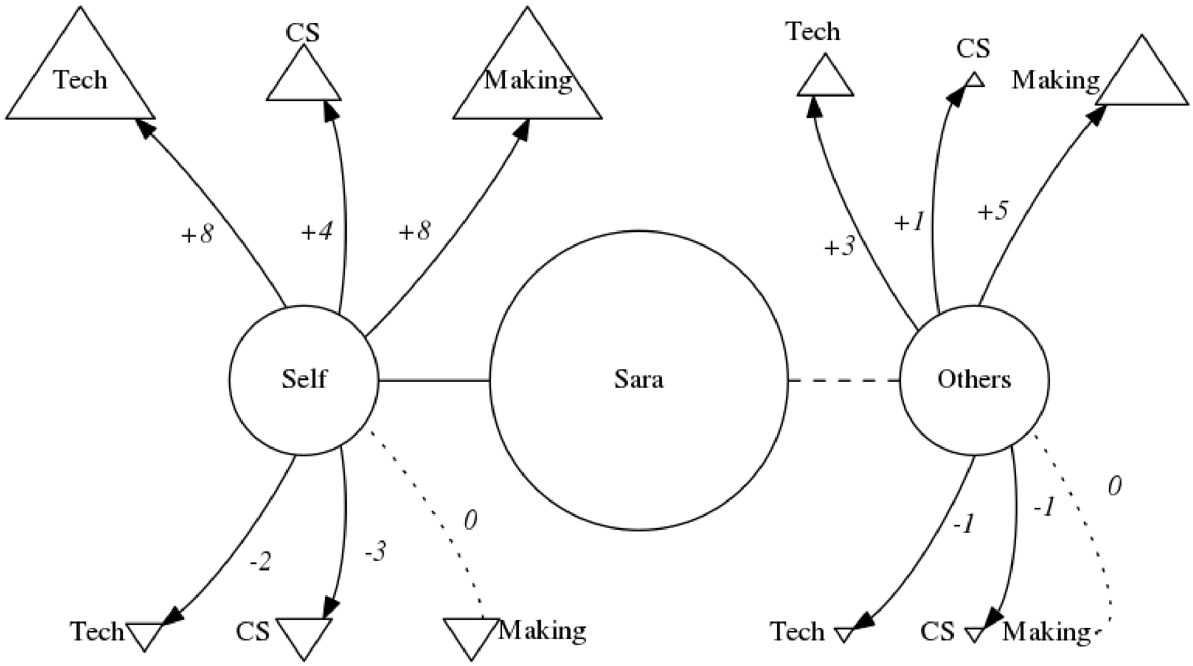

Figure 46. Sara's post-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Sara's post-camp interview.

Sara's Self-Depicted Relationships

For the self-depicted relationships to CS diagram, Sara used the ten recommended elements for all three sessions and only used the suggested relationship identifiers. Though differences across time were slight, some changes were evident from pre-camp to post-camp. For coding, the relationship transitioned from ability and like to like and interest. Similarly, for making things, the relationship descriptors transitioned from 'interest' to 'ability' and 'like' to 'like', dropping ability. Also, the relationship descriptor for CS students transitioned from "positive" in the pre-camp to "like me" in between- and post-camp conditions. Pre-camp tinkering was labeled as "interest;" between camp, the relationship was labeled with ability. After the camp, Sara labeled the self to tinkering relationship descriptor with "like."

Table 4

Sara's Self-Labeled Relations

Element	***Pre-MakerCamp***	***Between MakerCamp Weekends***	***Post MakerCamp***
Coding	Ability, like	Like, ability	Like, interest
Tinkering	Interest	Ability	Like
Making things with technology	Interest	Like, ability, interest	Like
Making things	Ability	Ability, like	Like
CS students	Positive	Like me	Like me

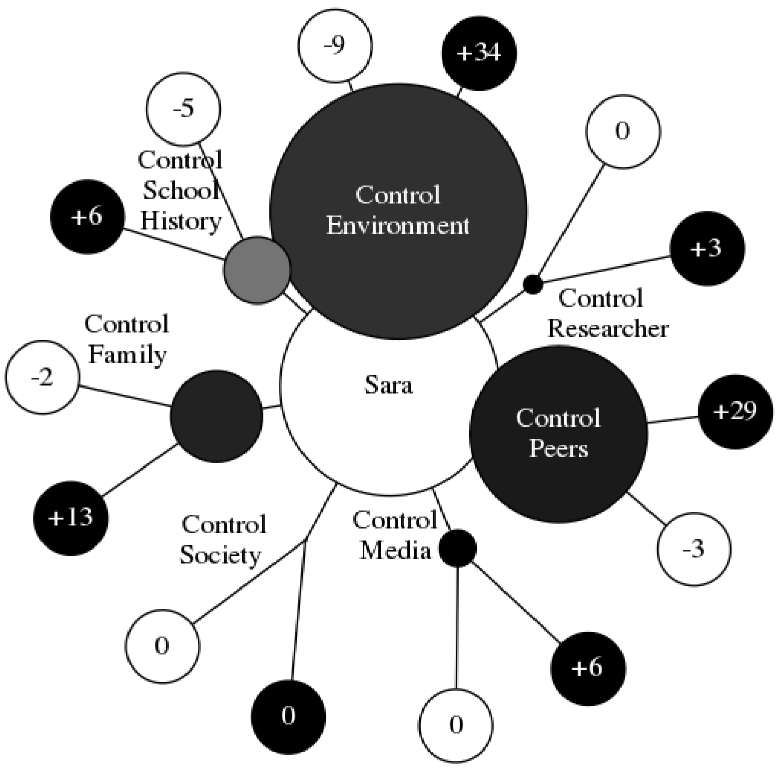

Figure 47. Sara's sources of control. This diagram illustrates the sources of control influencing Sara's behavior as discriminated from interviews.

Sara's Sources of Control

Though control exerted by the environment was the most common control observed for all participants, it was most evident with Sara, and closely followed by Lili, whereby most of the environment-exerted control was identified as likely reinforcing technology, CS, and making behaviors. Moreover, and likely not unrelated, Sara's interviews suggested substantive control from peers. Sara's familial interactions also seemed to have mostly provided reinforcing contingencies for technology, CS, and making (See Figure 47).

The control exerted by media was evident primarily in relation to discussions of games and games-related culture that suggested likely increased reinforcement of games related artifacts and influence of games related elements (cf. Walsh & Apperley, 2012). The observed control of the researcher also highlights the saliency of socially reinforcing contingencies for Sara.

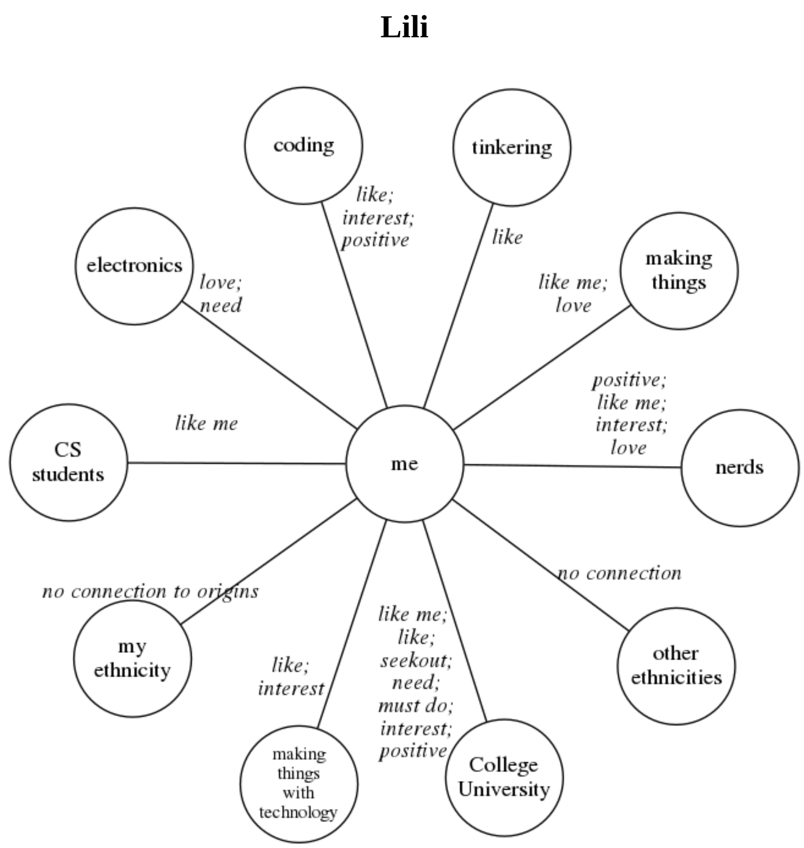

Figure 48. Lili's self-articulated relations pre-camp. This diagram reproduces Lili's pre-camp labeling of her relationships to topics possibly influencing interest in CS and making.

Lili Pre-Camp

The interview began with Lili being asked if she had heard of making, to which she replied, “Making, like creating?” She then explained that she had not heard of makerspaces or Maker Faires.

Lili’s articulation of makers, programmers, and the like. Next, Lili was asked to describe the kinds of people who create things with computers. She listed computer programmers, game designers, and Web designers. She was then asked whether she was such a person, to which she answered that she “enjoyed doing it.” The researcher then prompted Lili to identify whether she was that type of person and whether there was a stereotype or type of person who does such things. She responded that “usually, people envision [such types] being nerds with glasses and a grade point average of 130 [sic].” The researcher then observed that Lili was wearing glasses and questioned whether she was that type of person. Lili replied, “I’d say so. Yes.”

Lili and technology. In order to potentially glean elements of Lili’s interactional history related to such an assertion, the researcher asked Lili to recount her experiences with technology. She indicated that her interest in technology arose from her interest in magnet programs, specifically technology-oriented magnet programs, such as the programs she attended in middle school and high school. She then cited examples from her middle school, where she had created 3-D figures, and then high school where “we always made animations, web pages, and games.”

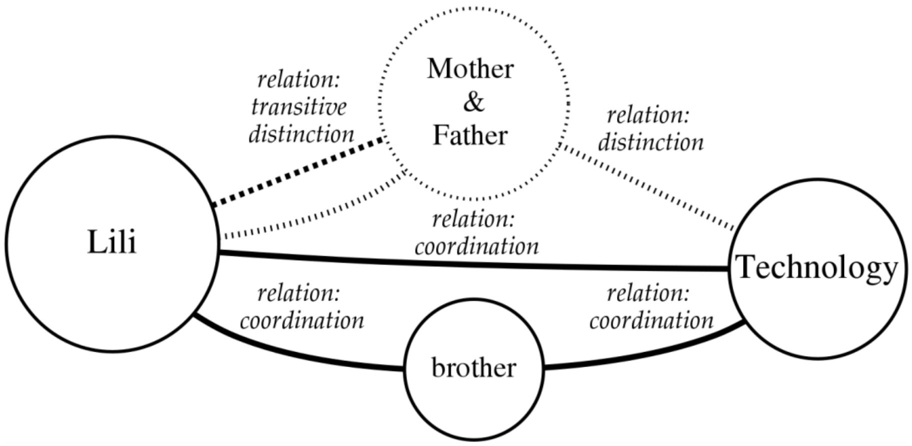

Figure 49. Lili's derived distinction to family. This diagram illustrates how Lili's shared relations to her brother and technology result in a derived relation of distinction (difference) from her parents.

Lili and her family. Lili explained, "[Her] brother, he's actually in an engineering program. So he uses a lot of technology from robotics and stuff like that." The researcher then asked Lili what influence her brother might have exerted on her interest in technology. She replied that he had encouraged her to go to the magnet program. The researcher then sought further clarification asking Lili if her brother "made things" with computers and technology. Lili explained that her brother "used to be in the robotics club, so he made robots and stuff." By contrast she explained that "[her] parents, they barely know how to open a tab on a web browser" (cf. Figure 49).

Lili and computers. Lili was then asked to specify the interactions that she had had with computers, programming, and in making things with technology. Lili detailed that she had "made several webpages and…two or three games using JavaScript and Unity" for class. She explained that she had taken part in such game making, as such technology classes were required by her magnet program, but also "because [she had] always wanted to make a game because [she] enjoyed playing them." She continues, "I thought making them would be easy. It turns out it's not." She then concluded her description of game making with the observation that "it's so fun getting to create something that you envision in your mind."

Lili elaborated "yes, [she thought she could solve] anything with the help from the interwebs." She was then asked to clarify what in her previous experience had led her to believe that she would be able to solve programming challenges. Lili explained that she had "learn[ed] about it on stuff like Codecademy."[18] Lili was then prompted to describe when she had begun using Codecademy. She explained that she had used Codecademy "either sometime in middle school or early on in high school," then "just continued," and "restarted using Codecademy" during her senior year.

Lili's social contingencies of *making* reinforcement. Lili was then asked to elaborate on her family's response when she told them about making things with technology. Her first example was that of her parents exclaiming, "No, it's a waste of time. Go and do your homework." She then provided a contrasting example of her brother stating, "Wow, you actually made that game, I don't believe it."

She was asked whether her friends created with computers and technology. She explained that many of her friends were in the same classes or did more visually oriented work involved "down below with Mrs. Jensen," in the visual arts classroom that is in the floor beneath the CS classrooms. The researcher then prompted Lili for specifics about their reactions to her making "cool things with computers and technology." Lili rejoined that they would respond with "I can do that better than you." The researcher then asked Lili if her friends could, in fact, do that better than her, to which she indicated "no."

[18] Codecademy is a free to use, learn-to-code website. https://www.codecademy.com/

Lili's prediction, reinforcement, and personal history. When confronted with the usual closing question, if she had any questions for the researcher, Lili asked if we would be using the Raspberry Pi and what it was. The researcher explained that it was a credit-card sized computer for controlling electronics such as LEDs, to which Lili responded that such an activity sounded interesting. The researcher prompted Lili to explain why it was interesting. After a short pause and noting that "it's hard to explain why it's interesting," Lili suggested that the interest was grounded in "the thrill of learning something new."

Lili then explained that she had "seen several videos of people who were trying to use batteries to light up LEDs or other kinds of experiments." Seeking the behavioral antecedents for this admission and its articulation, the researcher asked Lili why she had watched such videos. She clarified that "they popped up into [her] YouTube search engine when [she] look[ed] up 'creating cool stuff.'" Lili was then asked why she had searched out such information. She then concluded with "because I like making things and I thought it might be something interesting to try."

Lili's pre-camp discriminated interactional history. In the pre-camp interview, Lili indicated many positive interactions with technology, CS, and making for herself (+10, +9, +9) and others (+3, +4, +4; See Figure 50). She did relate aversive interactions with technology, CS, and making. However, the aversive interactions of others with technology clarified her own role in distinction to such people including her parents and emphasized similarities to her brother (See Figure 47) and others in her magnet program.

Lili between Makercamp Weekends

Beginning the between-camp weekends interview, Lili was asked what it was like to visit the makerspace for the first time. Lili responded that it was "a bit awkward, but [that] it was really fun as soon as we got to working with the actual program." She was then queried about what had been awkward. Lili explained that "you mostly don't know anybody there" and that "since [she] missed the first day, [she] didn't really know what to do."

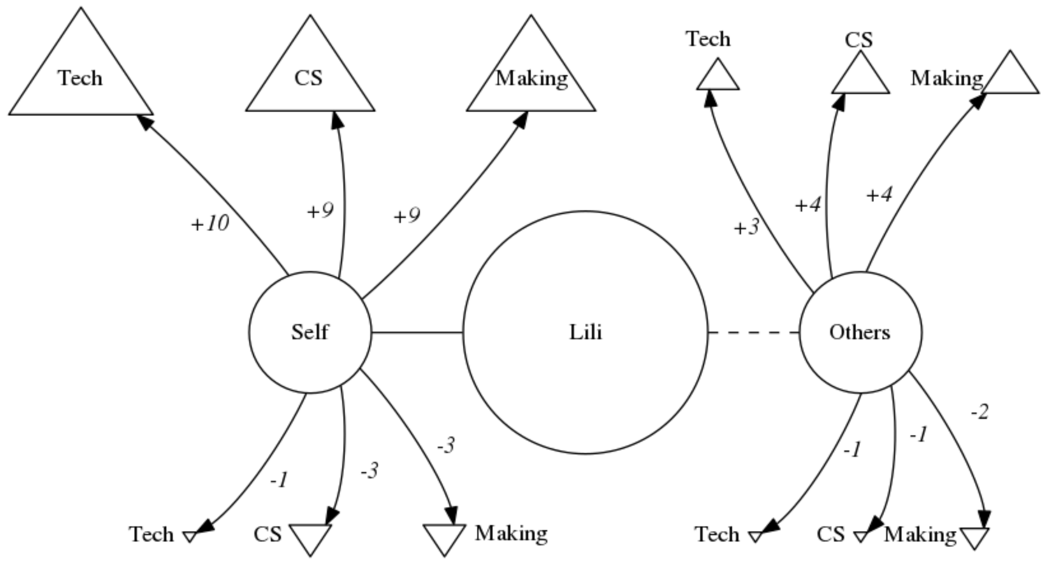

Figure 50. Lili's pre-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Lili's pre-camp interview.

Lili's makerspace observations. Lili was asked what she had thought of the makerspace. She noted "it was cold" and then that it was "like a little man cave." The researcher asked Lili if the makerspace had met her expectations. She replied that she "was expecting something more like the initial room…except with a line of old computer monitors." She also recalled looking at the laser cutter, the cutting boards, and some of the tool kits. In particular, Lili noted that she liked "looking at the laser cutter."

Lili's social contingencies following her makerspace visit. In order to discriminate potential social contingencies affecting Lili's makerspace attendance, she was asked whether she had talked with her family after her makerspace visit. She stated, "No…honestly, because they wouldn't know what it is or wouldn't get it." She was also asked if she had talked with her friends about the makerspace. Lili indicated that her friend thought it was "cool." Lili was then asked whether her friend might ever attend a makerspace. Lili indicated, "She has different kinds of interests but that she likes the idea."

Lili revisits programming. In the between-camp interview, Lili was asked whether and how her perceptions of programming had changed. Lili indicated that "not much [had] changed" and that she "still [thought] it's a cool thing to learn because it gives you an extra skillset." She was then asked her perceptions of the Scratch drag-and-drop programming environment and whether it seemed like programming. Lili expressed that it was programming, because "you're using it to manipulate and access things in the computer to change its initial condition."

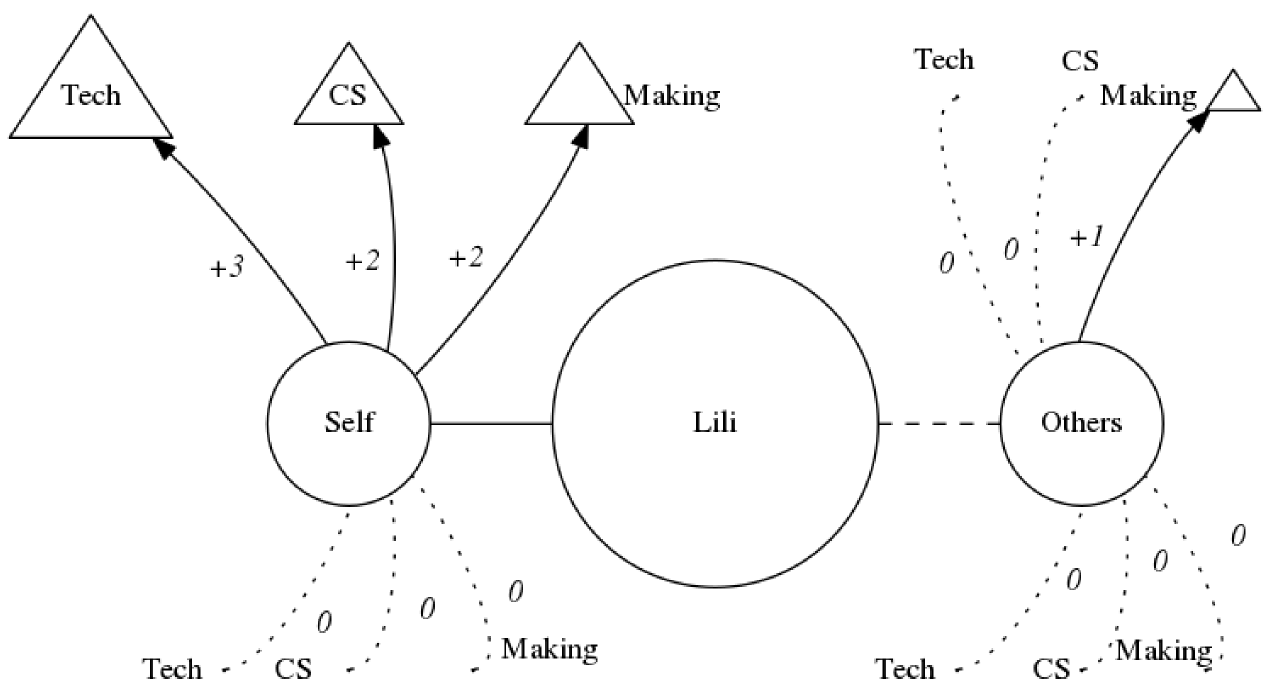

Figure 51. Lili's between-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Lili's between-camp interview.

Lili's between-camp discriminated interactional history. In the between-camp interview, Lili listed positive interactions with technology, CS, and making for herself (+3, +2, +2) but articulated few other interactions (See Figure 51). She did not observe aversive interactions for herself or others. She did identify herself in a positive reinforcing relationship with the makerspace, in contrast to her parents' relationship with the makerspace.

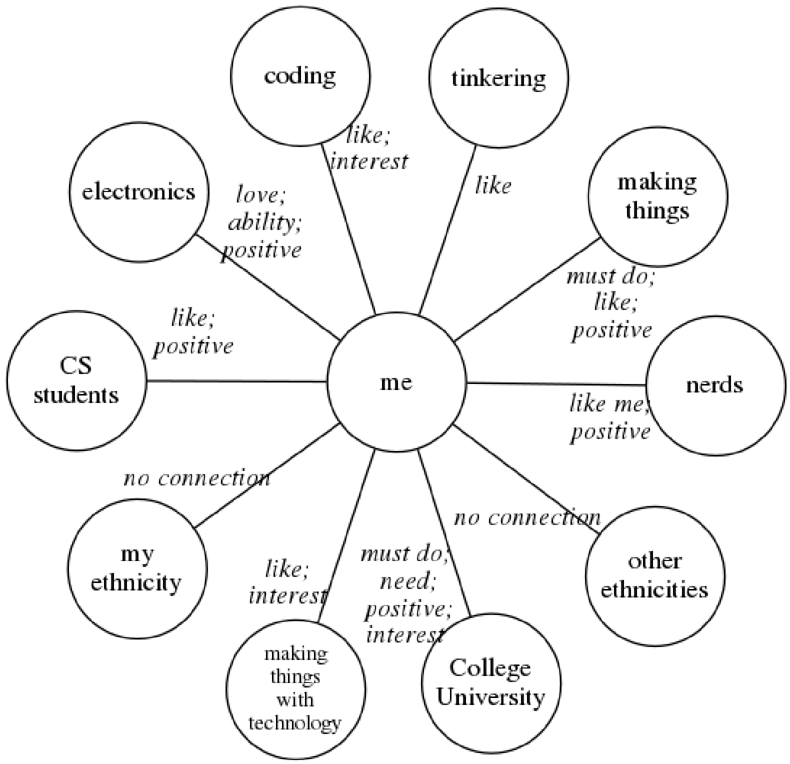

Figure 52. Lili's self-articulated relations post-camp. This diagram reproduces Lili's post camp labeling of her relationships to topics possibly influencing interest in CS and making.

Lili after the Makercamp

In the post-camp interview, the researcher first clarified with Lili that she had missed each Saturday, first for a relative's graduation, then her own, and attended each Sunday. The researcher then asked Lili her perception of the makerspace and she reiterated, "It looked like a man cave."

Lili's predictions of future makerspace attendance. The researcher questioned Lili as to whether she thought she would go back to the makerspace. She specified that she "would like to go back and try out the laser cutter and stuff like that." She was then asked what she might like to cut with the laser-cutter. Lili replied "probably 3-D puzzles or 3-D figures." The researcher then asked what had prompted her interest and whether she had seen examples of such 3-D cuttings at the makerspace. She explained that she “like[d] the examples like the big dinosaurs.”

Lili’s programming perspectives. Lili was asked again about her perspective on programming. Lili noted, “It was interesting” and explained it was similar to other programming experiences. She indicated that she “got a little lost” because she had missed some of the days. She also added that it was “pretty easy to catch up” with what had been taught. Lili was then asked to clarify her perspective on Scratch in contrast to Python. Lili explained, “Scratch seemed more like it was already laid out for you. You just had to put it together like a puzzle.” Describing Python, she noted “Python was more, here’s some code you can use. Do something with it.”

The researcher followed up asking if one environment, Python or Scratch, seemed more like “real coding” than the other. She succinctly stated, “Yeah, Python.” She was then asked why. Lili explicated that it was because she was “more familiar with coding being you type out the program.” She confirmed that it was an issue of familiarity. The researcher asked whether she would recommend Scratch or Python to introduce someone to programming. She replied, “Scratch would probably be easier for a beginner. Then have them transition on.” She explained that “on Codecademy they basically told us what to do and introduced us on how to do like specific tasks” and that then students “just group together to make [their] own thing.”

Lili’s relationship to self as programmer. Lili was then asked whether she would call herself a programmer. She affirmed, noting “a bit, not a pro.” Then, in order to gain greater insight to Lili’s interactional history, she was asked at what point, in her history, she would have called herself a programmer. She responded:

> *When I don't have to rely as much on looking up each and every code that I have to do. When I recognize the situation and am able to just go along with it instead of having to take longer and look through the internet.*

The researcher followed by asking, "When did that happen?" Lili explained that the transition had occurred after a larger independent game project at school. Providing more details about the time spent on the game project, Lili indicated that it had taken a month to make the game with one or two hours of class time used each day. Seeking further details, the researcher asked for specifics about the time required before Lili felt like a programmer. Rather than responding with a time, Lili noted that it was after she had completed a timer script. She was then asked why the timer script was such "a big accomplishment." Lili explained:

> *Because I had no idea what…how to do it. It confused me so much. Mr. Jensen went "Doesn't it look familiar?" Then it just suddenly popped into my head, "Hey, I could just do this." Like detach it from my other set of codes and just finish it up.*

Lili's future programming plans. At the end of the interview,[19] Lili was asked if she had any plans to program. She replied, "It depends." Consequently, the researcher asked about her college major. She responded, "Biochemistry." The researcher then remarked on the connections and commonality of Python and Matlab programming in the natural sciences, asking Lili if she was aware of such connections. She indicated that it was "a bit of a surprise" that biology majors did programming and not a surprise that chemists engaged in computer modeling.

[19] Minute 30:00 of 31:42

Lili's contingencies of makerspace reinforcement revisited. Lili was asked whom she spoke with at the space aside from her partner. She named the two other female research participants, Yesenia and Sara. The researcher observed that they were from the same school and asked what they had tdiscussed. Lili noted that "by the end of the session we ended up talking more about [Sara's] lasercut dinosaur than anything else."

Lili was then questioned whether she had spoken with any family or friends about what she had done at the makerspace. She indicated that she had told her father, who was "a bit curious about what [she] was doing," but that he indicated that he did not understand her and moved on to a new topic. The researcher then asked Lili to elaborate on whether she felt she "had accomplished something." She observed, "No, but it's kind of funny and sad at the same time, because I don't really have anyone to talk to except my brother, but since he's in college he's rarely at home."

In attempts to further illuminate the contingencies of social reinforcement, the researcher inquired whether Lili would remain in contact with her friend Suzy, whom she had met, worked, and frequently chatted with at the maker camp.[20] Lili indicated that they would "stay in touch, but probably not as much" as Lili would like.

Lili's self-articulated identity history. Diverging from the topic of resiliency,[21] Lili prompted a discussion of the trajectory of her identity over time. Lili began the discussion by noting "I think I have already mentioned…in elementary school…I was…I failed a lot." The researcher contradicted Lili's assertion by stating that he had not known that she had failed in elementary school. Lili affirmed stating that she "was horrible in elementary school." She

[20] A pseudonym
[21] Discussed separately

continued, explaining that from the third to the fifth grade she "had a bad attitude" and was "a crybaby."

The researcher asked Lili what had prompted a change. Lili observed that the change "just happened in middle school." She explained that "it was a different environment" and "instead of being in the same neighborhood [she] went to a magnet program." With the switch to the magnet program, "it just all seemed different."

The researcher asked if the people were more successful at the magnet school. Lili demurred, stating, "Maybe, I'm not sure how to answer that." Lili then indicated that she "didn't really have any friends" before switching schools. She was then asked if her friends in the magnet program had "good grades." She responded that she did not "know about their grades but that they [were] definitely kinder than elementary school" adding that "kids are cruel." She was then asked, aside from the students, to describe how the environment or teachers differed at the magnet program. She indicated that the teachers at the magnet program helped more than those in elementary school.

Lili's perceptions of Lili over time. Lili was then asked to articulate how her perception of "Lili" had evolved over time. She responded, "I just always feel down on myself so I always feel like 'oh I just have to do better than next time and if you don't then just like stab yourself in the brain' whatever."

In order to develop Lili's explanation, the researcher asked Lili to articulate her identity. She clarified that "[her] identity is crazy, loving *otaku*, [22] who likes computer art and wants to and tries to be funny even though she's not."

[22] Used to denote someone with fanatical interests, especially anime and manga.

Programming and Lili's nerd identity. Lili was then asked how she perceived herself in relation to programming. She replied, "I just like working with computers." The researcher then asked if working with computers related to being *otaku*. Lili explained that the *otaku* identity related more to art, such as in drawing favorite anime characters or *doujinshi*—"fan fiction but in manga style."

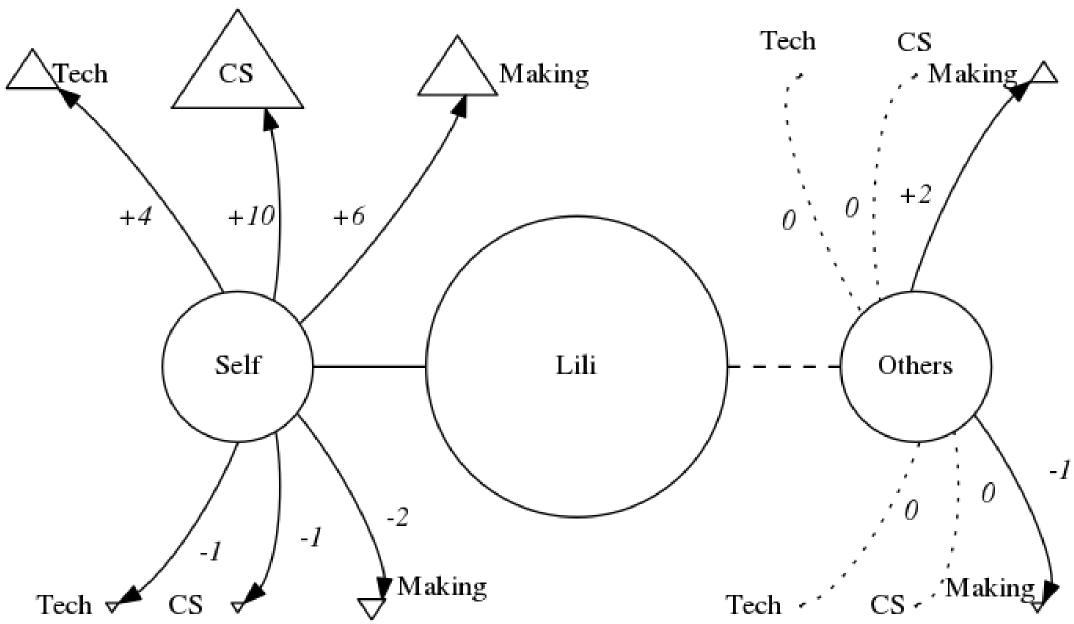

Figure 53. Lili's post-camp discriminated interactional history.

Lili's post-camp discriminated interactional history. Lili's post-camp interview spotlighted her positive interactions with CS (+10), making (+6), and technology (+4; See Figure 53). This interview was especially informative as it highlighted differing effects of signals, i.e. S^Ds, and conditioned reinforcers grounded in the environment, such as technology, relative to the effects of processes, such as conditioned and unconditioned reinforcing qualities of problem solving and task completion. The final interview tipped Lili's discrimination of positive interactions with technology (total +19), making (total +17), and CS (total +21) in favor of process descriptions, such as programming and creating rather than possession of technology or artifacts.

Though Lili provided descriptions of her family and others, their interactional histories, positive and aversive, were less apparent in this interview.

Lili's Self-Depicted Relationships

Owing to Lili's scheduling difficulties, a between-camp relationship diagram was not collected. Lili provided many similar relationship labels from across collection dates. Some evident changes in description include the transition for "making things" from "like me; love" to "must do; like; positive." Also, Lili used fewer descriptors for the self–college relationship after camp than in the before-camp condition.

Lili's Sources of Control

Analyses of Lili's interviews suggest significant control exerted by her environment. This discriminated strength of control is most likely related to her verbal proficiency, though a verbal proficiency that extends beyond simple talkativeness and is likely connected to the identified salience of school-related control. Considering the positive influence of school articulated by Lili (+23) and her academic successes, such as being one of few students to successfully program a JavaScript side-scrolling videogame, it is likely that Lili may be more behaviorally proficient in the VB patterns required in school, namely providing teacher-expected answers to questions (cf. Gladwell, 2008).

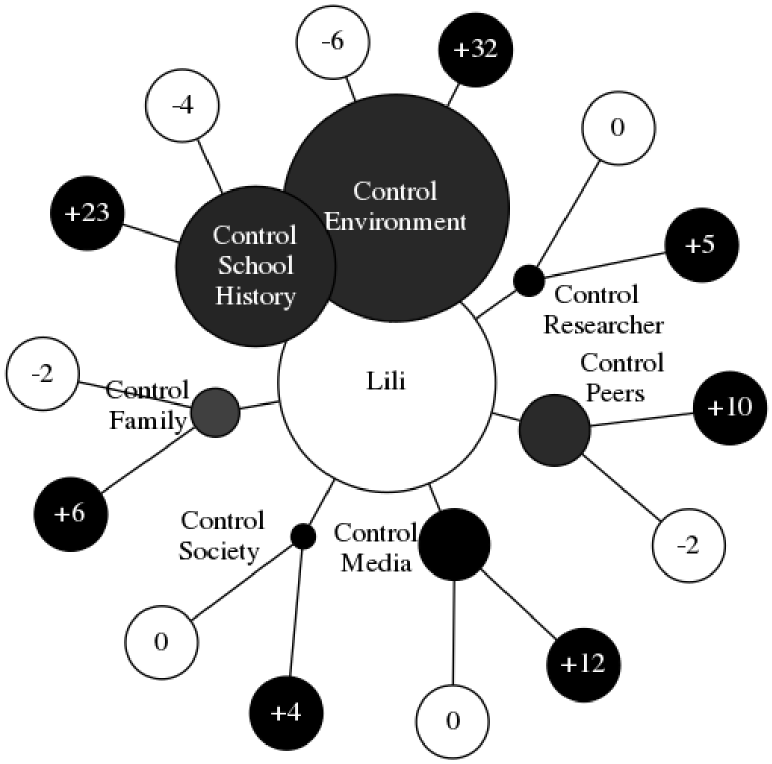

Figure 54. Lili's sources of control. This diagram illustrates the sources of control influencing Lili's behavior as discriminated from interviews.

Lili's discriminations of control highlight the frequent positive influences relating to technology, CS, and making (See Figure 54). Lili's articulated discriminations and susceptibility to surrounding contingencies of reinforcement might represent a multiplicative effect resulting from interactions with CS, technology, and making being commonly reinforced under the auspices of school and school-related contexts as an S^D. The researcher might have served as a signal, an S^D, for Lili's description of positive CS, technology, and making experiences, and possibly motivated Lili to ameliorate her answers.

Yesenia

Yesenia Pre-Camp

In the pre-camp interview, Yesenia indicated that she had not heard the terms maker or makerspace. She had heard the term Maker Faire but had not attended one and could not describe it. Yesenia was then asked to describe the types of people who create things with computers. She replied that there was "not really" a type and that such people were "just people who really enjoy being around computers and creating things, so they mesh."

Yesenia's self-articulated relations to making. Subsequently, Yesenia was asked if she is that sort of person. She replied, "Yeah, a bit." and proffered "digital art stuff" as an exemplar. She was then asked to provide examples. She detailed "using programs to create sort of a cover for different things." She next observed that she used programs such as Photoshop to create her art. Then, Yesenia was prompted to describe the role that making things with computers and technology occupied in her life. She answered that it was "a hobby," and elaborated that she "enjoy[ed] doing it" because "it takes time" and "it's entertaining."

Yesenia's social making contingencies. Yesenia was queried whether her friends create things with technology. She responded "yeah." She was then asked what her friends had to say about making things with technology. Yesenia indicated that they had said, "It's cool." Next, when asked whether her family made things with technology, she replied "no." The researcher then queried what Yesenia's family had to say to her making things with technology. Yesenia quoted her family as saying "that's a waste of time."

The researcher prompted for clarification asking why Yesenia made things with computers and technology if her family did not. She explained that she "[saw] it as a friend" whereas her family saw it "as wasting [her] eyesight on something that…they don't think will get her anywhere." Yesenia was then asked to describe something she had made. She described drawing a scene from a book for four hours over multiple days.

Yesenia's programming perceptions. Yesenia was prompted to describe the sorts of people who do programming. She responded "people who want to advance in technology."

Subsequently, she explained that she was not that type of person because she “really use[d] it for fun, not for the advancement of a thing” (cf. Figure 55). In order to shed light on her contradictory answer, Yesenia was asked what would make someone want to study computer science. She posited, “If they really just want to make something different on the computer…like if they want to make it do something.”

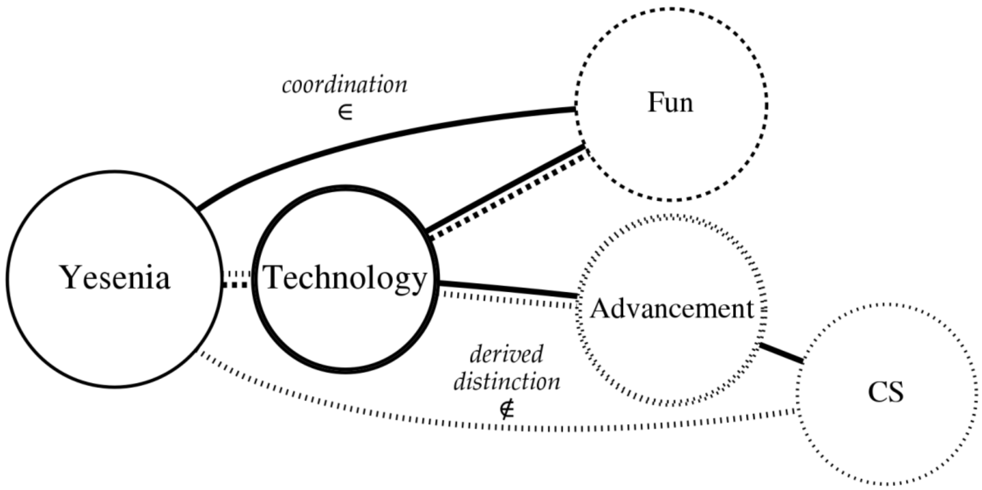

Figure 55. Yesenia’s articulated relation to CS. This diagram illustrates Yesenia’s derived relationship of distinction arising from distinction to those who use technology for advancement, whereas she uses it for fun.

The researcher then prompted Yesenia to elaborate on the likely differences between the interactional histories of people interested in CS and her own. She replied that “they’ve probably been exposed to it more and they have grown an interest to it while [she] hasn’t.” Yesenia was then asked which interactions she would need so as to be more interested in programming. She explained “if [she] learned more about it” and “if [she] found it easy.”

Yesenia’s prior interactional history with programming. The researcher next queried Yesenia about her prior experiences with programming. She recalled taking a class in New York, where she had previously lived. She noted that the class lasted a month and that it was “the teacher mostly lecturing on the software you use to program and…very little on how to actually program." She explained that she had taken the class because she thought it would "be interesting to learn, but no."

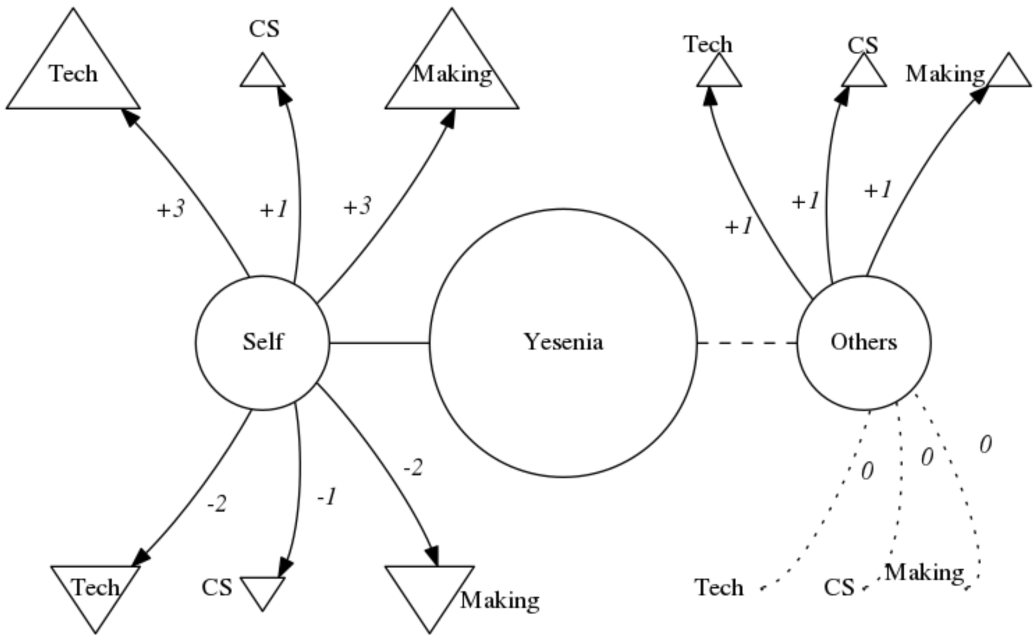

Figure 56. Yesenia's pre-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Yesenia's pre-camp interview.

Yesenia's pre-camp discriminated interactional history. In the first interview, Yesenia recalled almost balanced positive (+3, +1, +3) and aversive (-2, -1, -2) interactions with technology, CS, and making, including equally aversive and positive interactional histories with CS (See Figure 56). Perhaps most noteworthy was her family's aversive stance to CS and technology. However, although Yesenia's family were outwardly averse to CS and technology, their interactional histories were difficult to discriminate. Yesenia did observe slightly positive interactional histories for her peers with CS, technology, and making.

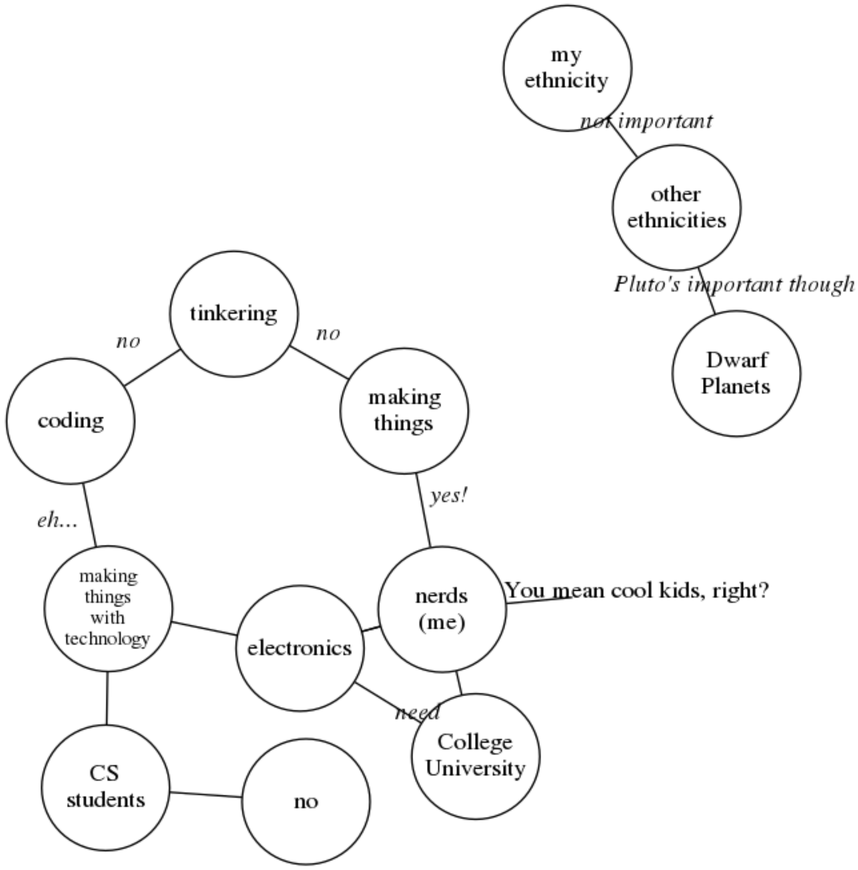

Figure 57. Yesenia's discriminated relations between camp weekends. This diagram reproduces Yesenia's between camp labeling of her relationships to topics possibly influencing interest in CS and making.

Yesenia between Makercamp Weekends

Beginning the between-camp interview, Yesenia was asked what she had noticed about the makerspace. She stated, "Well, it has all these…different kinds of technology." She was then queried as to which technology she had noticed. Yesenia then described the "laser thing that cut out the acrylic." She was then asked if the makerspace was as she predicted. She responded "pretty much, yes" except that it was smaller than expected.

Yesenia's social contingencies. In attempts to illuminate the social contingencies influencing Yesenia, she was asked if she had spoken with anyone at the makerspace. She indicated that she had spoken with one of the regular makers and that he "was explaining how the laser worked." Yesenia was then questioned if she had talked to him about anything else or even said anything to him; she indicated "no."

Yesenia's articulations of maker behaviors and maker identity. Yesenia was next questioned whether she knew what a maker was and whether she was a maker. She replied "maybe." Clarifying what being a maker depended on, she responded with "things, making things." The researcher subsequently asked if she made things, to which she responded that she no longer had the time or energy to make things.

Yesenia's predictions of makerspace behavior. Yesenia was next asked if she would return to the makerspace. She indicated "yeah…if they're having other types of classes." The researcher then questioned whether Yesenia might go to the makerspace "just to use the tools." She responded "maybe" stating that it depended on "what she'd like to make." She explained that the tools she would use would depend on what was available. Yesenia affirmed that she would use the acrylic. When then asked about any other materials, she replied, "Not that comes to mind."

Later[23] in the interview, after discussing the differences between makerspaces and schools, the topic of Yesenia's predicted participation with makerspaces was revisited. Yesenia affirmed that she would return to the makerspace and that she might go in order to work on an independent project. However, she indicated that she did not yet have any plans for an independent project.

[23] ~8:00 of 13:03 minutes

Yesenia's perceptions of makercamp activities. Approximately halfway into the interview,[24] Yesenia was questioned as to how she experienced the makerspace activities. She was asked if the activities were too hard at any point. Yesenia indicated that they had not been. Similarly, she was asked if they had been too "boring," to which she also responded "no."

Yesenia's social contingencies during makercamp activities. Yesenia was queried about the social contingencies concomitant with her participation in the makerspace activities; namely, she was asked about the experience with her partner, a younger male, approximately 12 years in age. Yesenia indicated, "He was a control freak. He liked to do things for himself, so I let him." The researcher then asked if the partner had done everything. Yesenia replied "yeah." The researcher then followed asking if had been boring for Yesenia if the partner was "doing everything." She explained that she had not been at the makercamp the day before, "so [she] was still kind of adjusting to everything."

Yesenia's discriminations of makerspaces and other environments. The researcher broached the topic of other classes, possibly similar to the makerspace, which Yesenia had previously visited. Yesenia indicated that the makerspace was a "hands-on activity" where "they try to teach you." Yesenia contrasted the makerspace and its hands-on activities with the class that she "took in New York a couple years ago. It was just like giving you all these vocabulary that you needed to know even while you weren't doing anything really with it." Yesenia was then asked to clarify whether the "whole approach" of the makerspace was different from school. She responded "not too different."

Yesenia's perceptions of self as programmer. Yesenia was asked if she had programmed prior to the makercamp. She indicated "no." She was then asked if, given the first

[24] ~6:00 of 13:03 minutes

weekend of makercamp, she felt as if she had programmed. She responded “no.” Yesenia then clarified that she “didn’t feel like [she] was actually making a program.” She elaborated that “it was just…mak[ing] a motor spin…and the light light up” asserting “that was pretty much it.” Yesenia was then asked to expound upon what would make it programming. She indicated that making “a different kind of program,” making “a new thing,” such as “as app or something,” would qualify as programming. The researcher followed by asking Yesenia if writing a program in Python to play a song after a button is pressed might qualify as programming. She responded “maybe” and clarified that having programmed or not was dependent on “making a program that [she hadn’t] seen before.”

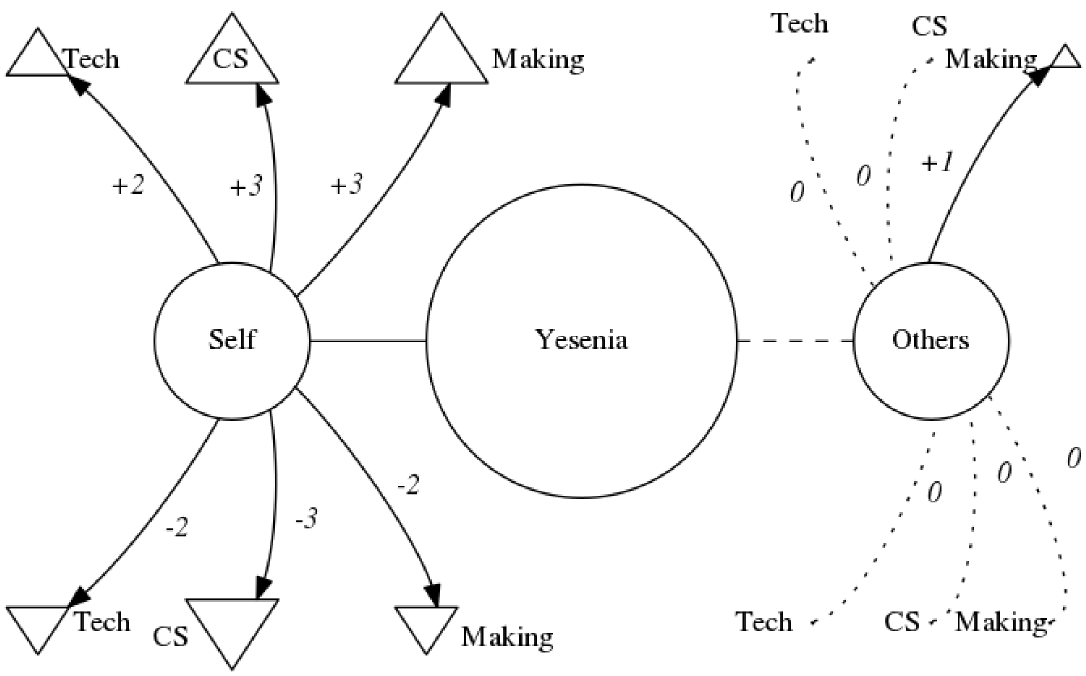

Figure 58. Yesenia’s between-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Yesenia’s between-camp interview.

Next, Yesenia was prompted to elaborate on the program she had been writing on Sunday and its relationship to programing. Specifically, the researcher asked Yesenia if the program she had been writing on Sunday would have felt more like a program if she had gotten further. Yesenia responded “sort of” and then elaborated that it “seemed too easy.” The researcher then queried whether “it would have felt more like programming” if Yesenia had typed in the commands rather than using drag-and-drop. Yesenia then explained “yes, because you’re actually doing those things yourself, not getting a certain aid to make it, yeah.”

Yesenia’s between-camp discriminated interactional history. In the between camp interview, Yesenia again described almost balanced positive (+2, +3, +3) and aversive (-2, -3, -2) interactions with technology, CS, and making for herself (See Figure 58). She did not discriminate interactions with technology or CS for others that were identifiable as positive or averse (See Figure 58).

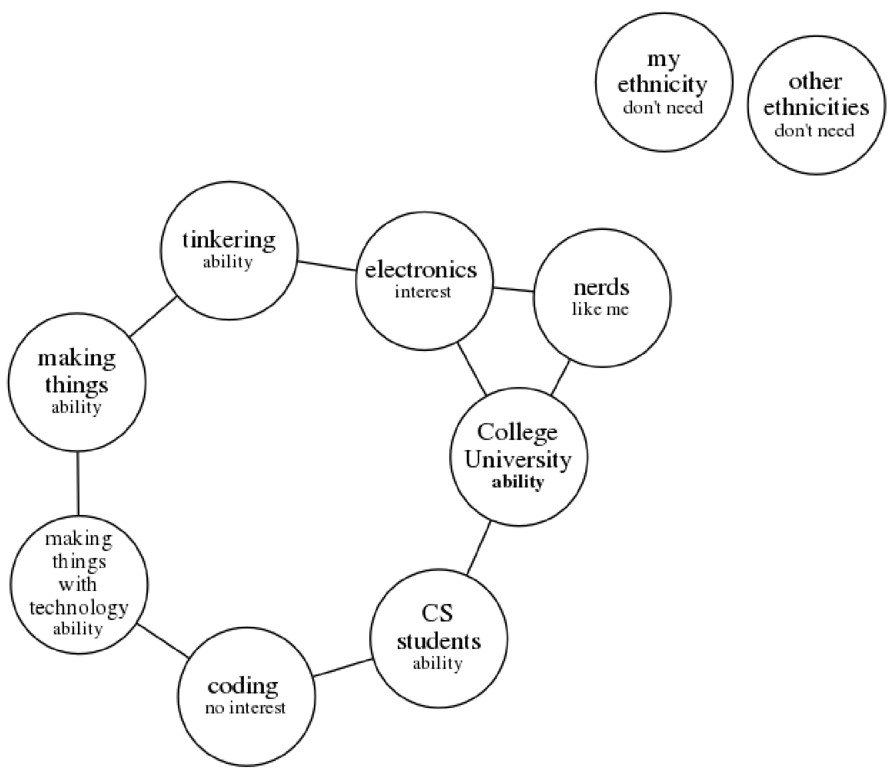

Figure 59. Yesenia’s self-articulated relations post camp. This diagram reproduces Yesenia’s post camp labeling of her relationships to topics possibly influencing interest in CS and making, whereby she omitted reference to self.

Yesenia after the Makercamp

In the post-camp interview, Yesenia was asked what she remembered about the makerspace. She replied, “it has *things*,” whereby she emphasized “things.” The researcher then asked Yesenia why she had attended all the makercamp days, except the first one. She explained that she “was bored” and that the makercamp “was fun” because she “got to learn stuff.” She was then prompted to explain how learning “stuff” in the makerspace was different than “googling” it. Yesenia clarified that the difference was that participants “actually get to do things not just reading it online.” She then elaborated, participants were able to “look and experience.” She explained that experience “involves doing.” She affirmed that doing involved talking and using one’s hands.

Yesenia’s social contingencies surrounding makerspace attendance. In order to illuminate the social contingencies affecting Yesenia’s makerspace attendance, she was asked what she had told her family about the makerspace. She replied, “It was a thing.” She then clarified that her family does not “really care about the actual details; they’re just like ‘Oh, you’re going here? Okay. We’ll drop you off and pick you up.’” The researcher then probed whether the family had said anything else. Yesenia replied “no.”

Yesenia’s predictions of makerspace behavior. In an attempt to elicit other examples of makerspace behavior, Yesenia was asked what she was doing with her summer. She responded that she was attending summer school to take swimming lessons. The researcher then probed whether Yesenia had plans to return to the makerspace. She indicated “not yet” and explained that the determining factor would be “if [she] need[ed] anything from there.” She was then asked what she might need from the makerspace, she replied “acrylic” as necessitated by lasercutting projects. The interview then queried whether she had any plans for laser cutting. She replied “not yet” and that she might have a project in the future.

The researcher then asked if Yesenia had “looked at” the Raspberry Pi that she took home from the makercamp. She indicated that she had shown her sister how to “make pretty lights.” She quoted her sister as stating, “Oh my God, lights” and being “so interested.” Yesenia commented that her sister was interested until she discovered that she could not make the lights turn purple, as Yesenia did not have a purple LED or a multicolor LED. The researcher then asked if Yesenia had learned anything about the Raspberry Pi that had not been covered in class and whether she had ideas for projects. Yesenia responded with “no” and “not yet.”

Yesenia’s self and family in relation to making. After she discussed her and her sister’s interactions with the Raspberry Pi, Yesenia was asked how she would describe a makerspace to outsiders. Her response was that a “makerspace is the space where you make.” Then, later in the interview after a discussion about resiliency, Yesenia discussed her family. Consequently, in an attempt to unearth possible examples of making or making-related activities in Yesenia’s family, she was asked about her parents’ professions. She explained that her father was a salesman and her mother stayed at home. The researcher then asked if the parents were “handy” and fixed things around the house. Yesenia replied “no” and explained that her uncles were called when something needed fixing. She later noted that she had approximately twenty-five uncles.

Yesenia’s self-articulated identity and relationship to CS. When asked about her identity, Yesenia first replied “that weirdo in the corner who doesn’t talk and is pretty smart” and then added “and insane.” The researcher then asked how Yesenia’s self-description related to CS. She replied that “considering that [she’s] insane, [she] will mess with everything” (cf. Figures 60). She was then asked if she saw herself as the type of person to do CS. She responded, “Yeah, like try at it.” She was next questioned if there was a type of person who does computer science and if she was that type of person. She explained that “people who like computers” are the ones that do CS and that she “kind of like[s] computers.” She was then asked if there was a type of person who programs which she answered stating, “Anyone can program.” The researcher then followed up asking her if she was part of anyone. She responded noting, “Anyone is everyone, yes.”

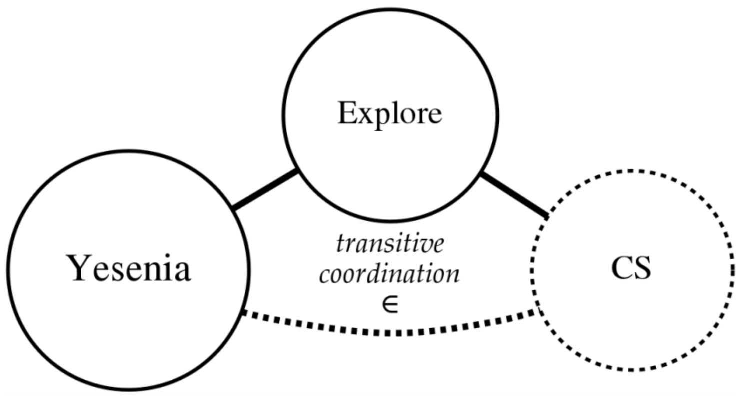

Figure 60. Yesenia’s derived relation to CS. This diagram illustrates Yesenia’s derived relation to CS owing to relationship to exploration.

Seeking further details of Yesenia’s discrimination of programmers and programming behavior, the researcher asked Yesenia if anyone could be “a good programmer.” She responded, “If they try,” clarifying, “Hard workers can, losers cannot.” She then explained that she was a hard worker as she “refuse[d] to lose.” When asked if gender or ethnicity played a role in CS, Yesenia replied, “No.”

Later[25] Yesenia was asked what relationship she perceived between herself and CS. As with her prior interview, she indicated that “it could be a hobby.” She explained, “I don’t see myself doing this for a job.” When asked why not, she replied that she did not know. She stated

[25] Approximately minute 17 of 35

that she wanted “a job that pays well and keeps [her] happy.” She was asked if that was not possible with CS. She explained that CS was “fun, just not overly fun.” The researcher then solicited an example of something that might be “overly fun.” She replied, “That’s the problem, I don’t know.” The researcher proffered a list of possible careers: mechanical engineer, petroleum engineer, teacher, principal, and firefighter. After which, Yesenia suggested that she would like to work as a video game designer. The researcher then observed that video game design might entail CS and asked Yesenia to clarify why she did not want to be a computer scientist. She emphasized that she did not “see [herself] being a computer scientist.”

Yesenia’s perceptions of programming IDEs[26]. Yesenia was asked her perceptions of Scratch, a drag-and-drop environment, and Python, a more traditional text-based programming language. She indicated that working with Scratch one “just drop[s]” whereas with Python, “you have to type and memorize things.” She further indicated that Python seemed more like real programming because “the drop one [Scratch], it’s too easy.” Yesenia was then questioned whether she saw any advantages to Python. She stated, “I don’t know about you, but I think typing is fun,” then adding that typing was “more enjoyable than drag and drop.”

Yesenia’s description of makers. For Yesenia to further elaborate on maker characteristics, she was asked, “What kind of people make?” She answered, “People who like making.” The researcher then prompted for further explanation, to which she replied, “People who want to do something with their lives.” In an attempt to contextualize and further discriminate Yesenia’s description, the researcher prompted Yesenia for another label citing the “hard workers and losers” example for programmers. She described “workers and the nobles” whereby “the workers…do things for the nobles.” Her use of worker and noble referenced a

[26] IDE is a commonly used abbreviation for Interactive Development Environment, the software used to write computer programs.

previously discussed dichotomy, from the discussion of resilience, when Yesenia had indicated that "peasants" had to work for their food, i.e. were creators, whereas "nobles" expected to be served, i.e. were consumers.

Yesenia, nerds, and CS. As some CS education researchers, e.g., Margolis et al. (2000), have emphasized the role of "asocial white nerds" in alienating demographics under-represented in CS, whereas other CS education researchers, e.g., Varma (2007), have indicated that "nerdiness" is a nonissue for many students under-represented in CS, the researcher asked Yesenia, a Latina, her perceptions of stereotypy and CS. When asked if computer science was "dominated by nerdy white guys," Yesenia replied, "I don't think so." Then when prompted about the stereotypical computer scientist portrayed on television, Yesenia detailed "nerdy, hunched-back, really skinny, googly-eyed guy typing on the computer." She then indicated that this portrayal did not keep her away from computer science, as she did not believe the stereotype.

Yesenia's articulated priorities. Given Yesenia's stated disinterest in CS as a career, the researcher asked Yesenia about her priorities. Yesenia explained that a priority for a career was that it "pay well" because her "family has been a little tight on money and [she doesn't] want to live that way…if [she's] ever to start [her] own family." She then elaborated that "fun" was a priority because she has "random bursts of depression" and, consequently, if something was not fun she might not want to do it anymore and would "sit in the corner and cry or something." She then summarized, "So, I have to enjoy it."

Yesenia and fun. In order to evoke more details regarding Yesenia's planned profession, she was then asked, "What makes something enjoyable?" She responded "story making" then elaborated "different kinds of adventures." She indicated "video games are fun" and "animations are fun." Yesenia was then prompted to articulate why such activities were fun. She explained that "if you make a video game, you get to see something cool, and you get to make something right before your eyes." She clarified, "Something, you know, that other people will enjoy." She then gave the example of "someone who really likes character design and they are fond of video games. They see that people really love the art design and they're going to love their job."

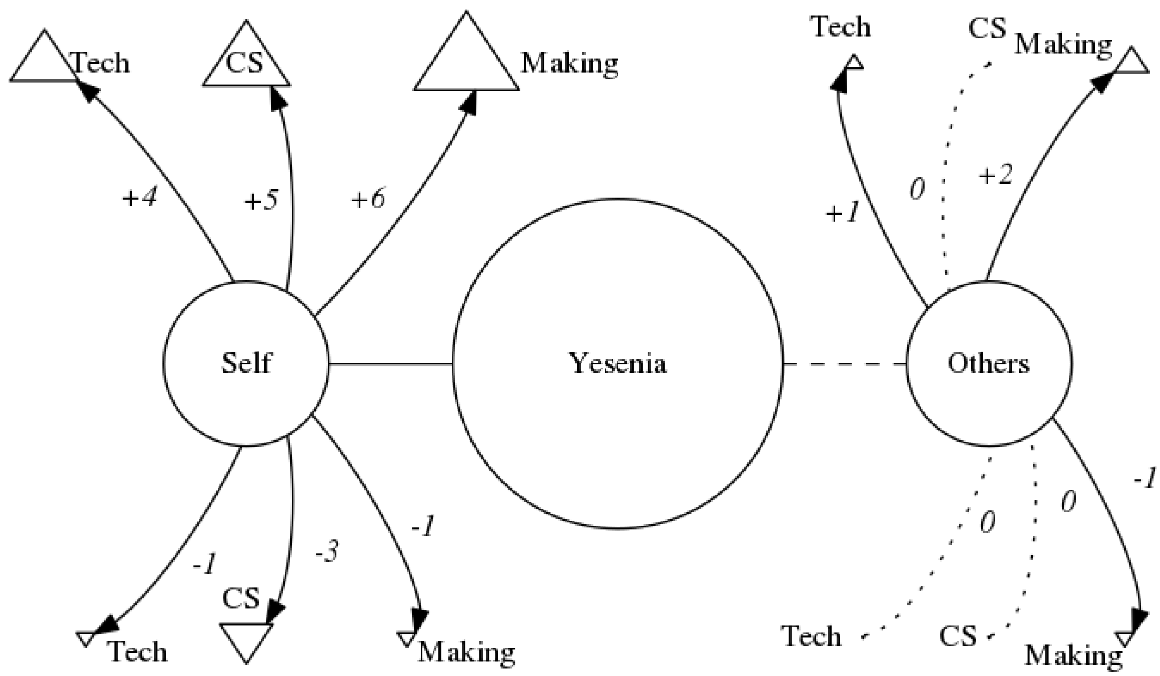

Figure 61. Yesenia's post-camp discriminated interactional history. This diagram illustrates the interactional history discriminated from Yesenia's post-camp interview.

Yesenia's post-camp discriminated interactional history. In the post-camp interview, unlike in other interviews, Yesenia recalled more positive interactions with technology, CS, and making (+4, +5, +6) than aversive interactions (-1, -3, -1), especially with regard to making See Figure 61). Though she identified some positive interactions of others with technology and making, the discriminations were slight.

Yesenia's Self-Depicted Relationships

Yesenia did not submit a pre-camp self-depicted relationship map; she packed it away after the interview and left with it. In comparing the between-camp and post-camp relationship maps, Yesenia's relationship descriptors evidenced fewer similarities to the example answer than did the answers of other participants. Most evident, Yesenia did not provide a "me" circle at the center of the diagram to the other components. Rather, she seemingly illustrated the connections among elements, which was encouraged on the answer sheet, and identified the relationship to her "self" through the use of relationship descriptors on the connections across items. The most apparent difference was the increased use of the "ability" relationship descriptor. Not used on the pre-camp diagram, the ability relationship descriptor (seemingly self-referential) was added to "college/university," "making things," "making things with technology," and "CS students" in post-camp data collection. In the pre-camp condition, Yesenia connects her and other ethnicities to "dwarf planets;" in the post camp condition, she labels her ethnicity and other ethnicities as "don't need."

Yesenia's Sources of Control

Overall, Yesenia suggested the greatest positive control arising in the environment (+15, -9). All other evaluated sources of control were balanced or almost balanced. Family (+7, -5), peers (+5, -5), and society (+5, -4) seemed to exert the next greatest amounts of influence (See Figure 62). Though the researcher may have influenced Yesenia's responding, the control exerted by the researcher was likely slight.

Considering the environment as Yesenia's greatest source of control, she seemed to be most commonly negatively reinforced. Whether it is her susceptibility to contingencies and other aspects if her environment, her low frequency of positively discriminating verbal behavior was more suggestive of escaping stimuli than being reinforced by them.

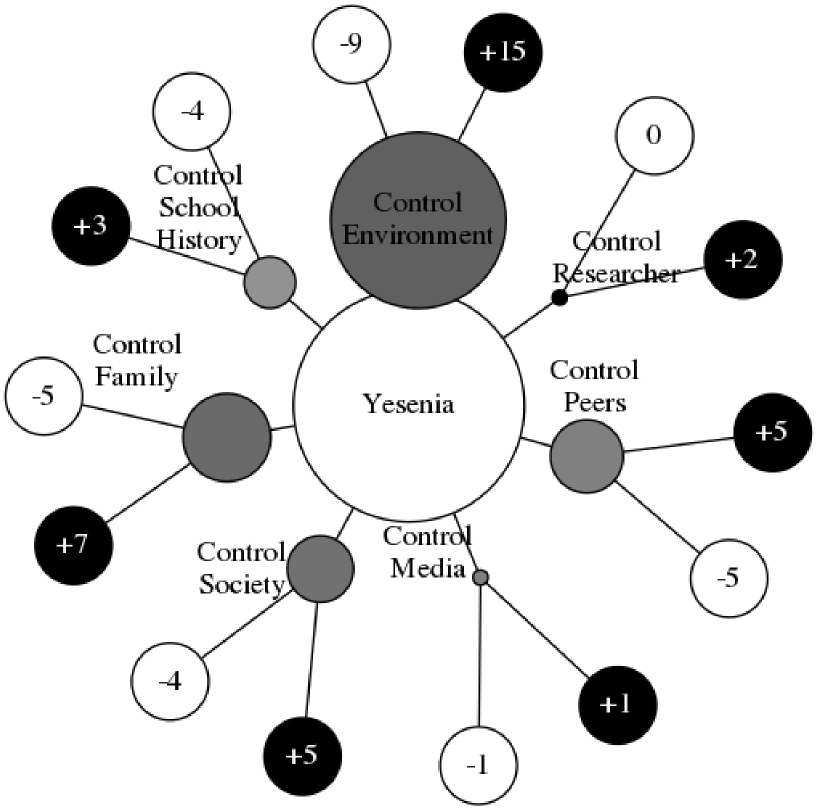

Figure 62. Yesenia’s sources of control. This diagram illustrates the sources of control influencing Yesenia’s behavior as discriminated from interviews.

Summary

Examining participants’ interactional histories, the discrimination of positive and aversive interactions present discernible patterns. The shared topographies are reflected, to an extent, in patterns of participation at the makercamp (See Chapter Five). In pre-camp interviews, Osiel articulated little prior interactional history with CS for himself and little for others. This pattern was also common for Luis, who provided some, but few descriptions of positive interactions with CS and making. It is perhaps unsurprising that Luis and Osiel did not attend the second weekend of camp.

Table 5

Luis, David, and Osiel Total Interview Interactional Histories

Participant	History	Technology		Computer Science		Making	
		Positive	Averse	Positive	Averse	Positive	Averse
Osiel	Self	19	15	4	14	10	9
	Others	4	2	2	2	2	1
Luis	Self	13	3	7	2	7	1
	Others	4	1	1	0	2	0
David	Self	21	2	14	2	13	4
	Others	5	0	2	1	6	1

Differences in David's profile may have worked noticeable effects. Topographically, David emitted an almost prerequisite number of CS, technology, and making discriminations given the interview context—perhaps as much a result of social contingencies as prior history.[27] However, David did discriminate strong interactional histories with making as positively reinforced and supported by his grandmother, mother, and father.

Table 6

Sara, Lili, Yesenia Total Interview Interactional Histories

Participant	History	Technology		Computer Science		Making	
		Positive	Averse	Positive	Averse	Positive	Averse
Sara	Self	22	4	14	4	20	4
	Others	16	2	7	2	17	2
Lili	Self	19	3	21	4	17	5
	Others	3	2	4	1	7	3
Yesenia	Self	9	6	11	7	12	5
	Others	3	0	1	0	4	1

[27] Which cannot currently be meaningfully disaggregated

Yesenia was a bit of an antithesis to David. She discriminated little familial, especially parental, support for CS, technology, and making. Though little overt reinforcement was identifiable from Yesenia's parents, her parents did have an identifiable history of taking her to extracurricular, technology-related activities. Consequently, the nonverbal and nuanced verbal contingencies may have positively reinforced Yesenia's CS, technology, and making participation. For example, being driven to and picked up from classes may have positively reinforced her attendance and in-class behaviors. Further, given Yesenia's description of familial interactions, attending classes may have been negatively reinforcing, i.e., Yesenia *liked* to get out of the house.

Similarly, Lili indicated a lack of overt parental support for CS, technology, and making. She did, however, identify strong interactional histories with CS, technology, and making at school. She also indicated a similar interactional history with CS, technology, and making to that of her brother with whom she discriminated as being in a frame of equivalence.

Sara articulated positive interactional histories with CS, technology, and making for herself. Sara emphasized her family's positive interactions with CS, technology, and making. Also, Sara identified pronounced reinforcement for science, technology, engineering, art, and math (STEAM) activities from her family as well as identifying socially reinforcing contingencies within the makerspace. Moreover, Sara discriminated the reinforcing nature of the making process itself. It is therefore most likely not coincidental that Sara attended all four days of the makercamp.

Equipment and Processes: Conditioned Stimuli and Behavioral Training.

A similarity shared across all participants was an identification of the technologies and equipment available at the makerspace. The availability of equipment seemed to function as an

MO for planning maker projects. The role of equipment as an MO or S^D for making-related behaviors, here verbal behaviors, was apparent in several conversations to lesser and greater extents.

The *noesis* of lasercutting as motivation for making. Participants' descriptions of the laser cutter illuminate *the experience of using makerspace equipment*[28] providing motivation, i.e., as an MO, for maker projects. The first step in the process was discrimination. Among the aspects of the makerspace that Osiel discriminated, the laser cutter was perhaps the element most quickly discriminated. Discrimination was followed by a prediction of susceptibility to contingencies of lasercuting-related reinforcement. Yesenia and Lili both expressed interest in the laser cutter, but had no definitive plans for its use. The likely beneficial control exerted by equipment such as the laser cutter, as environmental stimuli, became more apparent with Luis, David, and Sara.

Luis succinctly stated that when he was in an environment with 3-D printers that he had "lots of ideas" for what he could make, and no ideas given the absence of such stimuli. Similarly, the presence and perceived access to the 3-D printer led David to planning to develop replacement printings and last wax castings of medals. Even more so, having access to the laser cutter prompted Sara to design and cut a Spinosaurus dinosaur from acrylic using the laser cutter.

These emissions of making-related behavior suggest convergent effects of interactional histories and sources of control[29] highlighting the role of behavioral impetus (cf. Spiker, 1970). Namely, previously reinforced behaviors are more likely to be emitted and the stimuli controlling their emission are more likely to be discriminated and influence behavior. For all participants,

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[28] Italics are added to clarify that it is the experience of using makerspace equipment that provides motivation.
[29] Of course, interactional histories and strength of control are related given that control strength is a function of interactional history.

the conspicuous, more discussed, expensive makerspace tools—the 3-D printer and the laser cutter—evoked the greatest attention.

That expensive, “flashy” tools such as the laser cutter promote interest in makerspaces is not new information for makerspace curators (cf. Chang, 2013). Makerspace leaders, including those at 10bitworks, acknowledge that tools “get people in the doors” (Davis in conversation, May 2015). This is certainly helpful, but only as a first step. The next step must be *habituation*, namely increasing participants’ familiarity with tools, their affordances, and then the skills involved in making with such tools (cf. Bijou, 1976; C. L. Hull, 1934).

The role of tool habituation. Although the specific makercamp activities were new to all participants, including using Scratch GPIO and GNU/Linux, Osiel, the participant indicating the least generalized work with technology, excepting specialized graphics work, reported the most aversive responses, such as confusion, to the makercamp activities. Familiarity and prior discrimination training with technology and the environment appeared conducive to engagement and susceptibility to makerspace-related contingencies of reinforcement.

For example, Sara was alone in overtly discriminating the presence of tools and supplies. She also indicated the most positive interactions with making and technology, which culminated in her independent lasercut Spinosaurus project.

Schedules of Reinforcement and Problem-Solving Processes

From a CS education perspective, Osiel, Yesenia, and Lili emitted behaviors most promising for a CS learning trajectory (cf. Perkins, Hancock, Hobbs, Martin, & Simmons, 1986). Namely, they seemed content to work longer without praise or success, i.e., on thinned schedules of reinforcement. Being comfortable with less frequent reinforcement, can and did, to an extent, result in longer time on problem solving tasks. This result is similar to an example from Perkins et al. (1986) who found that those CS novices who continue to purposefully test code variations were the most successful, followed by those who tested haphazardly, and that those novices who stopped programming upon encountering problems so as to wait for teacher intervention were the least successful.

Lili and Yesenia both detailed prior experiences with prolonged problem solving on a thinned schedule of reinforcement. Lili's recollections made apparent that she had been previously acclimated to a thinned schedule of reinforcement in her games design class, in programming a 2-D JavaScript game. Additionally, she recollected creating *doujinshi* (fan art), which was suggestive of a thinned schedule of reinforcement. Lili's acclimation to a thinned schedule of reinforcement for problem solving, and related skills of abstraction, seemed to support her success in the makerspace environment.

For Yesenia, the example of a thin schedule of reinforcement was recreating a drawing over a period of days. Similarly, Osiel continued through the break to create the Raspberry Pi Morse code program. His persistence may have been related to his prior artistic endeavors or perhaps grounded in negative reinforcement to escape the perceived social stigma of his difficulties with the program. Osiel's lack of attendance on Sunday may have been due to his confusion and by not attending he could escape an uncomfortable situation, i.e., negative reinforcement, escaping a situation, may have been the dominant source of control.

Social Contingencies

Social contingencies seemed to factor pronouncedly into makerspace engagement. The three female participants communicated most with one another and even transitioned to collaborating on Sara's Spinosaurus project. By contrast, Osiel was the least socially engaged and only attended the camp one day. Luis spoke with Sara on Days One and Two but did not return for the second weekend of makercamp. Sara, however, indicated communicating frequently with study participants and others from the makerspace. She attended all four days and exceeded others in participation by developing her own independent project.

Lili and Yesenia were soon immersed in Sara's social group—a clique of the three female participants and another female high school student attending the makerspace. Yesenia attended all three days after having missed the first day of makercamp. Lili attended both weekends only missing to attend her cousin's then her own graduation.

Conclusion

The analyses of interviews examining participants' interviews situated around a makercamp highlight overlapping insights from constructionist (e.g. Seymour Papert & Harel, 1991) and radical behaviorist perspectives on learning. the contingencies surrounding learning, i.e., the physical and social environment, should be structured so as to naturally facilitate (control) the emission of target behaviors.

Instructional Design Implications

Conspicuous displays of technology can influence the emission of covert maker and CS-related behaviors, such as planning, and overt behaviors such as talking and making. However, the presentation of such galvanizing stimuli can only be an introductory step. The goal is rather to transition to thinned schedules of reinforcement, more reliant on project-based reinforcement. Novice makers, some more than others, will need greater support in transitioning to thinned schedules. This transitioning to thinner schedules of reinforcement is a guiding principle of instruction design. Namely, larger projects are broken up into smaller sub-goals to support learners in transitioning to a more project and problem-solving oriented approach. Behaviorally, such a transition is described as the habituation to thinned schedules of reinforcement and operant conditioning of the problem-solving process itself as a reinforcer. Purposeful, explicit framing of larger projects as "more serious" may help in maintaining greater longitudinal interest through the value-altering effects. Indeed, conscientious and purposeful framing of target molecular and molar behaviors may best support longitudinal engagement trajectories including project completion and maker identities.

An Example of Framing Effects on CS Participation

Participants' perceptions of the Scratch GPIO and Python were only based on familiarity to an extent (See Figures 63 and 64). Though participants could all be identified as CS beginners, their exposure to CS related concepts varied slightly. Osiel, Yesenia, David, and Luis were all in the researcher's web design class, where they used DreamWeaver[30] for HTML, CSS, jQuery, and some JavaScript programming. They all demonstrated the most basic beginner level proficiency with programming, which was to be expected. Sara had slightly more programming experience as she was completing a first-year CS class, where she was not academically successful. Lili was in the Web design class, but also attended a more advanced game design class where students programmed games using JavaScript and Unity. Among the participants, Lili was the demonstrably most experienced and successful programmer.

Reactions to Scratch. David and Osiel did not respond aversely to Scratch GPIO. Lili and David observed that Scratch and text-based programming with Python were functionally equivalent, which was true given the scope of the makercamp. Luis, Yesenia, and Sara, by contrast, professed greater familiarity with and appreciation for text-based Python. Their positive valuations of Python, however, were divorced of actual programmatic accomplishments, but rather seemed to be products of habituation and framing.

[30] A very common IDE for web design.

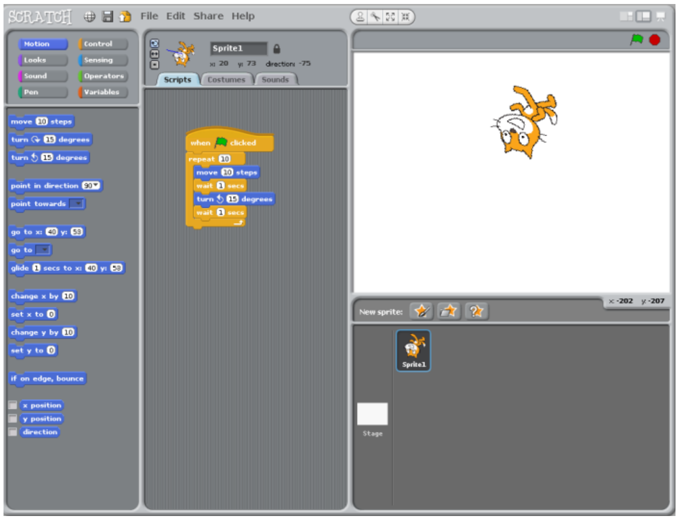


Figure 63. The Scratch IDE. This figure is a screenshot of the drag-and-drop programming environment Scratch.

As participants were not generally unfamiliar with or averse to drag-and-drop environments, it was the novelty and context of using a drag-and-drop environment for programming that elicited adverse responses. Such aversion to programming environments based simply on framing and concomitant perception has been documented elsewhere. For example, DiSalvo (2014) investigated novice perceptions of drag-and-drop and text-based programming environments and found that the valuation of such environments depended on career plans more than on success or experience with programming. In short, students, here and with DiSalvo (2014), responded to what they perceived should be a programming environment more so than to the affordances of the environment.

Framing CS and Making for Learning

Therefore, owing to the effects of framing suggested above and throughout participants' interviews, it becomes important to cultivate students' familiarity with tools and develop increased verbal proficiency for discussing such tools. Moreover, students should perceive themselves as makers and respond as members of a broader maker class, i.e., self ∈

makers. Instructional design should support students in explicitly articulating connections between CS and making. Then, the students' combinatorial, derived responding of self and CS should be purposefully and gradually shaped, i.e., tasks should be arranged so that students talk about themselves as active and knowledgeable users of CS.

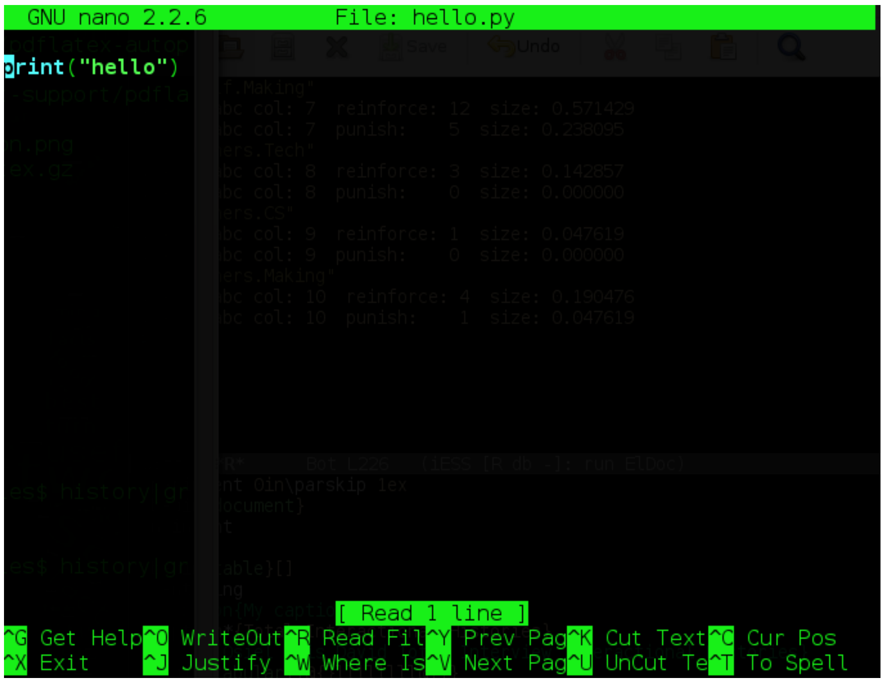


Figure 64. Text-based editor. This figure is a screenshot of the Nano text-based editor used at the makercamp for writing simple Python programs.

Connections between technology and making can be used at first. For example, students can be provided with demonstrations of "cool" technology and opportunities to use such technology. However, in order to achieve more longitudinal gains, including more productive behaviors (lifelong learning and maker trajectories), then participants will need to be transitioned to project-based problem-solving as a conditioned reinforcer. This behaviorally articulated assessment reflects the common knowledge of makerspaces that having flashy "toys," such as laser cutters and 3-D printers, gets people in the door. However, there is currently little behavioral guidance for purposefully transitioning novice makers to more longitudinal maker identities better suited for maintaining interest in longer and more difficult projects.

Certainly, constructionists and makers commonly know that project-based behaviors are the goal, but there is little identifiable discussion of explicit environmentally grounded roadmaps, social or physical, to shape maker trajectories. Rather, there is a tacit assumption that if students spend enough time making, the transition will occur naturally (cf. Litts, 2015). Indeed, such transitions may occur spontaneously, as fruit and berries may grow without planned intervention. As with horticultural intervention, the return on makerspace interventions would be much greater if the germination and cultivation of maker molar behavioral trajectories was planned. Targeted maker identity intervention plans could be used to assist students with less history and fewer sources of maker influence outside of school.

CHAPTER FIVE: RESULTS FROM MAKERCAMP DISCOURSE

Chapter Four focused on illuminating participants' personal histories that framed their experience with the makercamp activities. Chapter Five focuses on identifying behaviors, in situ, that may comprise or support CS and maker identities. In particular, the researcher focused on identifying verbal behaviors, as they are the identity behaviors most easily identifiable by outside observers. Similarly, verbal behaviors more readily suggest the antecedents, relational frames, discriminative stimuli, and consequences influencing their emission.

Guiding Questions

The behavioral–phenomenological investigation presented here was designed to abstract the ebb and flow of verbal behaviors emitted by participants as well as the antecedents and contingencies influencing those behaviors. In order to behaviorally illustrate novice experiences in a makerspace, the researcher sought to identify:

1. What were the frequencies of physical environmental-stimuli, social stimuli, and motivating factors as precursors to the emission of verbal behavior?
2. What were the frequencies of participants' verbal behavior types, i.e., mands, echoics, intraverbals, or tacts?
3. What are the frequencies of social and physical consequences to the emission of verbal behavior?

Criteria for Participant Analysis

Extreme case sampling was used in order to highlight differences in participants' verbal behaviors and related molar maker behaviors (Onwuegbuzie & Leech, 2007). Participants were selected on characteristics identified during interviews and makercamp attendance. Osiel only attended one day of the makercamp and articulated the least history of self and familial reinforcement in relation to CS and making during the pre-, between-, and post-camp interviews. By contrast, Sara attended all four days of the makercamp and indicated the greatest history of self and familial reinforcement in relation to CS and making during interviews. the verbal behaviors of two very different participants are presented to better highlight differences in makerspace participation by novices with different histories (cf. Berland, 2008).

Data Analysis

The data presented here are the analyses of the conversations from the two selected participants recorded during the four-day makercamp. Each participant wore a digital voice recorder attached to her or his collar for the entirety of the camp. The data were then transcribed and analyzed by the three core components of behavior: antecedents, behaviors, and consequences (See Figure 65). The unit of analysis was each contiguous emission of verbal behavior, i.e., statements not interrupted by other speakers or long pauses.

Coding of Antecedents, Verbal Behaviors, and Consequences

Antecedents to a participant's verbal behaviors were not identified as simple "either/or" factors, but rather as a listing of defining traits including other's verbal behavior (OVB), environmental factors (ENV), or motivating operations (MO).

Verbal behaviors were discriminated into the four main types of verbal behavior as identified by Skinner (1957b):

- *echoics,* simple repetitions of verbal behavior,
- *tacts*[31], describing something in the environment,
- *mands,* including commands, demands, and requests for something,

[31] It was necessary to focus on the more pragmatic definition of tact, stimuli in the environment, rather than considering elaborated tacts.

- *intraverbals*, which are controlled by other speakers' verbal behavior, and combinations thereof.

to capture an overarching sense of what was being said and why, i.e., the purpose of each participant's statement, verbal behaviors were classified as to whether they described: the self, for example, statements including *I* and *we* (cf. Fies & Langman, 2011), human behavior, physical elements, such as saws, computers, and cables, or social elements, such as friendship and small talk. Consequences were coded as to whether the effects of participants' statements were physical, such as being given a tool, or social, for example, resulting in further conversation with another person.

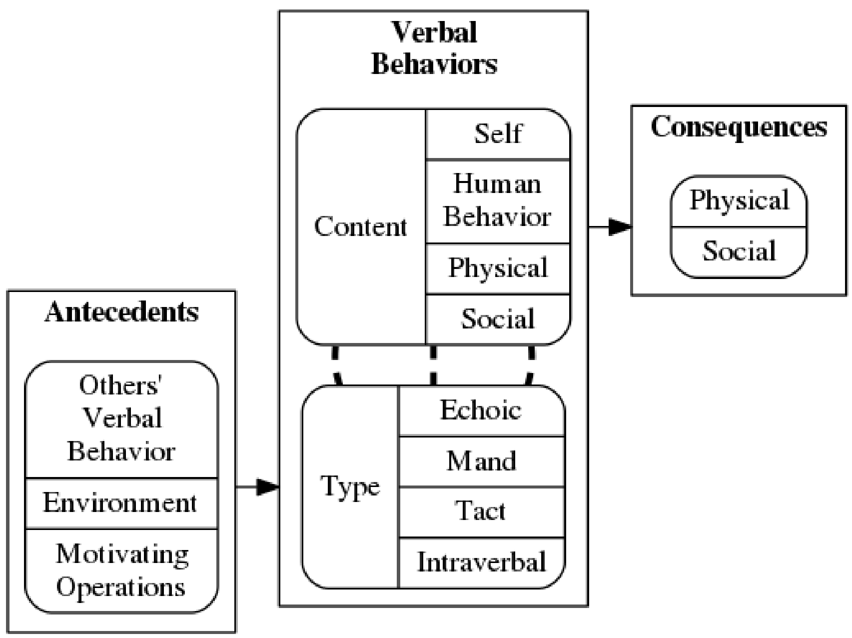


Figure 65. Discriminated core components of verbal behavior. This diagram illustrates the categories used to label the antecedents, verbal behavior types, and consequences (ABCs) of conversation in this study.

Hybrid Notation

In Tables 7, 8, 9, 10, and 11, antecedents, verbal behaviors, and their consequences (ABCs) are list co-occurring components ordered by frequency. For example, if a verbal behavior was discriminated as being preceded and likely controlled by a combination of other's verbal behavior (OVB), environmental stimuli (ENV), and motivating operations (MOs) then OVB-ENV-MO would be written. If other's verbal behavior was the only discriminated antecedent, then OVB alone was written. This is similarly true for the tabulation of verbal behaviors (e.g., utterances that contained intraverbals, mands, and tacts would be written as IV-MAND-TACT) and consequences. The order of terms does not represent the order in which they occur or strength of control. Making any assertions about significance in order or strength of control (and additional consequent IOA) lies outside the scope of this study.

Findings

The study was designed to explore novices' behaviors in a makerspace, identifying and analyzing the precursors that could evoke participation in the makerspace, as well spotlighting those elements of the makerspace experience that punish or reinforce participation. The design of the study was informed by the promising field of embodied cognition research and its relationship to novice CS and other STEM learning. As the study presented here was a primarily qualitative, behavioral–phenomenological investigation, there was no null hypothesis in a formal sense. However, the review of literature prefacing this study as well as the increased physicality of a maker environment suggested to the researcher that the physical environment might play a primary, possibly overshadowing, role in influencing novice experiences and behaviors within a makerspace. By contrast, social antecedents, social interactions, and social contingencies were most commonly observed. Rather than obfuscating these roles, physicality and social factors complemented each other in determining the makerspace experience for novices.

Osiel and Sara's Emissions of VB

Looking at the raw data for Osiel and Sara, a few differences become immediately apparent. Osiel spoke much less than Sara and went for longer periods without speaking. During Osiel's only day (Day 1, approximately 4 hours) at the makercamp, he produced 84 verbal episodes, with a mean length of 5.2 words, a median length of 4 words, a mode of 1 word, and a maximum utterance length of 34 words. Sara was, by comparison, more verbose with more daily utterances (377, 633, 727, and 706), commonly longer utterance means (10.8, 9.4, 9.4, and 12.8 words), and longer maximum utterance lengths (247, 299, 127, and 244 words). The word count of her median (5, 4, 6, 7) and modal (1, 1, 2, 1) utterance lengths were similar to Osiel's.

The Antecedents of Makerspace VB

The disparate numbers of antecedents to Osiel and Sara's VB (Tables 7, 8, 9, 10, 11) further reflects their differences in frequency of talking during the makercamp. However, a quick glance at the relative frequencies of antecedents reveals a pattern for both participants. Namely, *other's verbal behavior* is the most frequent antecedent for both participants, followed by environmental stimuli, then motivating operations. Overall, 79.8 % (67/84) of Osiel's utterances had other's verbal behavior as a noticeable antecedent. For Sara, the ratios were similar and increasingly higher over the four days (77.5%, 292/377; 82.3%, 521/633; 85.0%, 618/727; 93.5%, 660/706).

The Environment. The next most commonly discriminated antecedents of participants' verbal behavior were environmental stimuli. For Osiel, environmental stimuli, alone and in conjunction with other's VB and motivating operations, were discriminated as antecedents for

61.9% (52/84) of his utterances. By contrast for Sara, although environmental stimuli often preceded her utterances (48.3%, 182/377; 46.0%, 291/633; 41.0%, 298/727; 23.7%, 167/706), they were less commonly the antecedents to her VB as the camp progressed.

Value-Altering Effects and Motivating Operations. The least commonly discriminated antecedent for VB were the effects of motivating operations (cf. Langthorne & McGill, 2009; Laraway et al., 2003; Michael, 1993a). MOs were discriminated for 38.1% (32/84) of Osiel's utterances. For Sara, MOs were discriminated less frequently (27.9%, 105/377; 6.6%, 42/633; 3.0%, 22/727; 5.9%, 42/706) as antecedents.

Table 7

Osiel day 1 ABC Flow- Multiple

Antecedents		Verbal Behaviors		Consequences	
OVB	33	IV	25	SOCIAL	67
OVB-ENV-MO	20	IV-MAND	19	SOCIAL-PHYSICAL	17
OVB-ENV	14	IV-TACT	18		
ENV-MO	12	MAND	13		
ENV	5	TACT	4		
		IV-MAND-TACT	2		
		MAND-TACT	2		
		IV-MAND-ECHOIC	1		

Table 8

Sara day 1 ABC Flow – Multiple

Antecedents		Verbal Behaviors		Consequences	
OVB	171	IV	192	SOCIAL	279
OVB-ENV	81	IV-MAND	85	SOCIAL-PHYSICAL	67
ENV-MO	46	IV-TACT	37	PHYSICAL	31
OVB-ENV-MO	32	MAND	13		
ENV	20	TACT	9		
MO	19	IV-MAND-TACT	9		
OVB-MO	8	IV-MAND-ECHOIC	9		
		IV-ECHOIC	8		
		MAND-TACT	7		
		IV-TACT-ECHOIC	3		
		MAND-ECHOIC	2		
		TACT-ECHOIC	1		
		MAND-TACT-ECHOIC	1		
		ECHOIC	1		

Table 9

Sara day 2 ABC Flow - Multiple

Antecedents		Verbal Behaviors		Consequences	
OVB	339	IV	243	SOCIAL	521
OVB-ENV	169	IV-MAND	198	SOCIAL-PHYSICAL	101
ENV	83	IV-TACT	103	PHYSICAL	11
ENV-MO	26	IV-MAND-ECHOIC	36		
OVB-ENV-MO	10	IV-MAND-TACT	29		
OVB-MO	3	IV-ECHOIC	10		
MO	3	TACT	7		
		MAND	5		
		IV-TACT-ECHOIC	1		
		MAND-TACT	1		

Table 10.

Sara day 3 ABC Flow - Multiple

Antecedents		Verbal Behaviors		Consequences	
OVB	420	IV	298	SOCIAL	543
OVB-ENV	193	IV-MAND	183	SOCIAL-PHYSICAL	184
ENV	92	IV-TACT	136		
ENV-MO	10	IV-MAND-TACT	36		
MO	7	IV-MAND-ECHOIC	20		
OVB-MO	5	MAND	20		
		IV-ECHOIC	16		
		TACT	12		
		IV-TACT-ECHOIC	5		
		IV-MAND-TACT-ECHOIC	1		

Table 11.

Sara day 4 ABC Flow – Multiple

Antecedents		Verbal Behaviors		Consequences	
OVB	521	IV	297	SOCIAL	645
OVB-ENV	126	IV-MAND	201	SOCIAL-PHYSICAL	61
ENV	27	IV-TACT	87		
MO	12	IV-ECHOIC	34		
OVB-MO	10	TACT	30		
ENV-MO	9	IV-TACT-MAND	25		
OVB-ENV-MO	1	MAND	14		
		IV-MAND-ECHOIC	9		
		TACT-MAND	6		
		IV-TACT-ECHOIC	2		
		MAND-ECHOIC	1		

Frequency of Verbal Behavior Types

In keeping with other's verbal behavior (OVB) as the primary antecedent to the emission of VB, intraverbals (IV), i.e. under the influence of others' verbal behavior, were the most commonly identified type of verbal behavior. For Osiel, 77.4% (65/84) of his utterances contained intraverbals. Intraverbals were even more common with Sara, whereby the majority of her utterances had higher percentages of intraverbals (91.0%, 343/377; 97.9%, 620/633; 95.6%, 695/727; 91.4%, 645/706).

Asking Questions, Making Requests, Commands, and Demands. Mands were the second most identified form of verbal behavior. For Osiel, mands, i.e., questions, commands, and requests, were identified in 44.0% (37/84) of his utterances. Sara also frequently asked questions, made requests, and gave commands (33.4%, 126/377; 42.5%, 269/633; 35.8%, 260/727; 36.3%, 256/706).

Describing the Environment. Tacts, the description of stimuli present in the environment, were the third most commonly identified aspect of Osiel and Sara's verbal behavior. Osiel tacted his environment in 31.0% (26/84) of his utterances. Sara tacted her environment as much and more than Osiel did, with higher overall frequencies and lower relative frequencies (17.8%, 67/377; 22.3%, 141/633; 26.1%, 190/727; 21.2%, 150/706).

Repeating Others' Words. Echoics are verbal behaviors that share point to point correspondence with others' recently emitted verbal behaviors (M. Sundberg, 2004). Here, the count of echoics includes partial echoics, not complete repeats of entire phrases, as well. For example, stating, "Butter?" after hearing "Could you please pass the butter?" would be coded as a mand and an echoic. For both participants discussed here, echoics were the least frequently identified form of verbal behavior. Osiel only emitted one statement with an echoic (0.01%, 1/84). Sara emitted more echoics but also with low relative frequency (0.07%, 25/377; 0.07%, 47/633; 0.06%, 42/727; 0.07%, 46/706).

Contingencies of Maker VB

Lastly, the consequences of behavior, i.e., the contingencies that maintain or punish behavior, were considered. Namely, contingencies were identified as having social (e.g. conversational) consequences, physical consequences (e.g. being given a component or having code changed), or both. All of Osiel's interactions were identified as having social consequences, whereby 79.8% (67/84) were identified as having purely social consequences and 20.2% (17/64) as having social and physical consequences. For Sara, contingencies were also most commonly social:

- Day 1 –day one 74.2% purely social, 17.8% social and physical, and 8.2% simply physical;
- Day 2 – 82.4% purely social, 16.0% social and physical, and 0.2% simply physical;
- Day 3 – 74.8% purely social and 25.3% social and physical;
- Day 4 – 91.5% purely social and 8.7% social and physical.

The Flow of Makerspace VB

In addition to the frequency of antecedents, verbal behavior types, and consequences of VB, the flow of conversations could be visually analyzed (See Appendix D). Both the arc diagrams with the composite labels (in Appendix D) and the disaggregated antecedents, verbal behaviors, and consequences, including relative and absolute frequency tabulations [See Figures 66 and 67], highlight that OVB is most commonly followed by intraverbal behavior and the consequences are most commonly social. Examining Tables 7-13 and the arc plots in Appendix

D highlights that intraverbals commonly co-occur with mands, which could often extend the verbal exchange. Similarly, social and physical occur commonly, but physical consequences alone are rare.

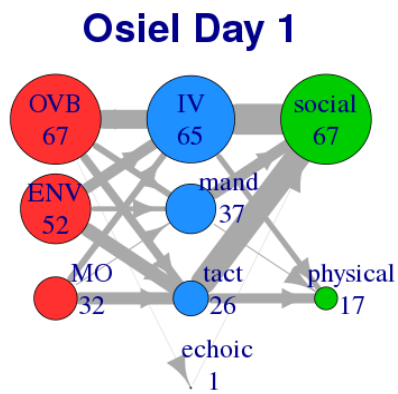


Figure 66. Flow of Osiel's Verbal Behavior Day 1. This chart illustrates the disaggregated flow of antecedents, verbal behaviors, and their consequences identified for Osiel.

Summary

The guiding questions at the beginning of the chapter reflect the three main behavioral distinctions of components in verbal flow: the antecedent, the verbal behavior itself, and the consequence of that behavior. It is important to focus specifically on verbal behaviors, as they provide the foundations for and represent those elements that undergird engagement and problem-solving in makerspace and other STEM environments (D. Barnes-Holmes et al., 2000; Baum, 2005). By identifying the most salient characteristics of VB and the frequency of their emission across novice makers, we might begin to better behaviorally understand disparate experiences in a makerspace. Here, an extreme case presentation of participants' VB experiences was selected to facilitate contrasting differences between maker trajectories.

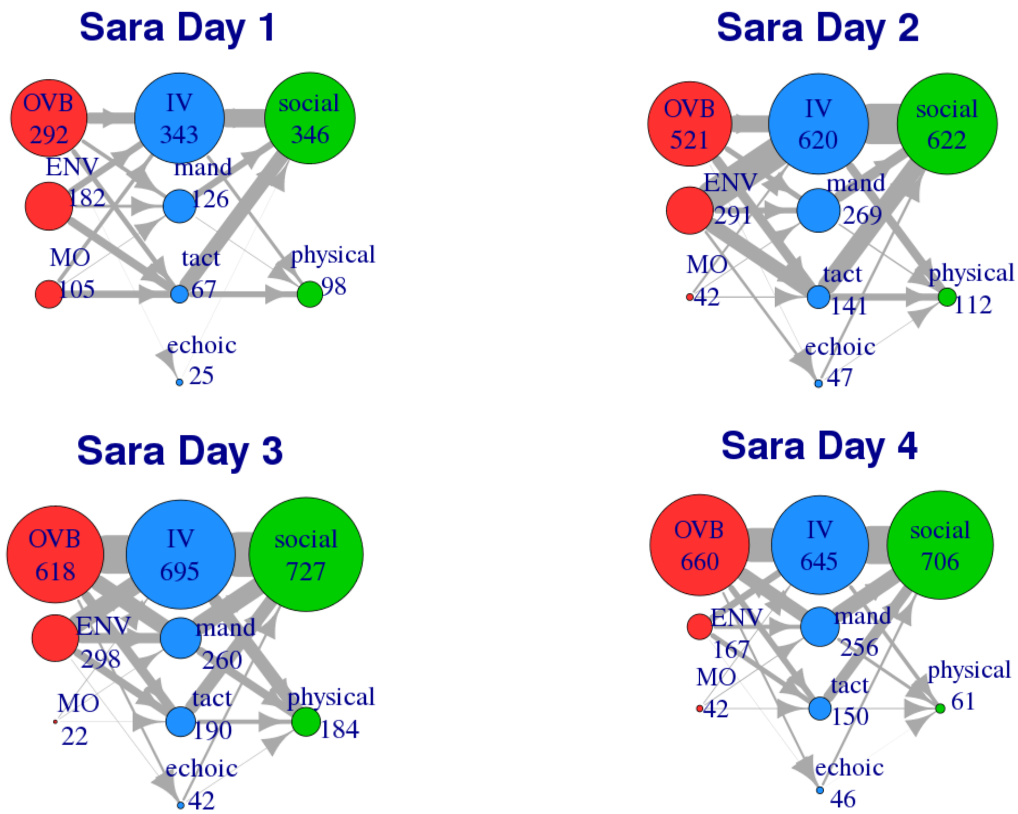


Figure 67. Flow of Sara's Verbal Behavior Days 1, 2, 3, and 4. This chart illustrates the disaggregated flow of antecedents, verbal behaviors, and their consequences identified for Sara.

The Antecedents of VB

One might naively assume that in a task-based, tool- and technology-rich environment such as a makerspace, and that given makercamp "challenges," the environmental stimuli might most identifiably affect the emission of verbal behavior. For both Osiel and Sara, the verbal behaviors of others were the most common antecedent of behavior. Environmental stimuli were the next most common antecedent—in conjunction with the verbal behaviors of other. The numbers of emissions prompted solely by environmental stimuli or motivating operations were few. Certainly, one might expect percentages and numbers of VB preceded by other's verbal behavior to be raised by conversations. One tangential conversation alone could raise rates of OVB as the antecedent to VB quickly for someone as loquacious as Sara.

Though the volume of emissions varied, the relative frequencies for less talkative Osiel and more talkative Sara shared marked similarities: a preponderance of OVB as antecedent and OVB in conjunction with environmental stimuli as a close second. The high relative and total numbers of OVB as antecedents suggests, but not unequivocally, that social factors primarily influence novices' makerspace experience and behaviors, that social factors exert greater influence than environmental factors, and that social factors determine the influence of environmental factors. Given that talking usually occurs between two or more people, it might seem rushed to make sweeping pronouncements about someone's behavioral experiences solely based on the antecedents to their VB. More than just OVB as a precursor to speaking, it is the commonality of intraverbals and the preponderance of social consequences in conjunction with the greater frequency of OVB as an antecedent to VB that suggests the primary importance of social factors for novices experiencing a makerspace.

The Problem with MOs. As for motivating operations, there are a few possible reasons for the low numbers. One reason could be that there were in fact few value-altering effects identifiable to raters. Another possibility rests on the empirical and pragmatic groundings of behavior analysis. It is difficult to observe value-altering effects when many antecedents of behavior may be more simply attributed to environmental stimuli or others' verbal behavior. Consequently, the identification of MOs as antecedents was commonly predicated on the elimination of the other possible antecedents. It is, therefore, probable that the low rates of identified MOs attests more to the behavioral pragmatism of coding requirements than necessarily to limited influence of MOs on participants.

Participants' Verbal Behavior Types

The total and relative frequencies of verbal behavior types emphasize the primarily social nature of verbal behavior and the substantively social nature of participants' behaviors in the makercamp environment. Both Osiel and Sara emitted primarily intraverbal behavior. For Sara, this seems perhaps less surprising. A tally of her verbal behaviors suggests that she might easily be described as talkative. By contrast, Osiel only made 84 utterances over a slightly longer than four hour period. The overall (65 of 84) and relative frequency (77.4%) of Osiel's utterances that were intraverbal in nature, including those solely intraverbal (25, 29.8%) without requests or questions, highlights the primarily social aspect of the makercamp.

This social aspect is further emphasized by the prevalence of mands: following intraverbals, the next most common type of behavior were mands—requests for information and materials. For both Osiel and Sara, mands were most commonly questions.

The Environment. Tacts, descriptions of present environmental stimuli, were verysecond most frequent types of verbal behavior, especially common in combination with intraverbals.[32] Though the social, intraverbal aspect of interactions was most apparent, tacting the environment occurred relatively commonly. Of note, a higher percentage of Osiel's VB contained tacts (31.0%) than did Sara's (17.8%, 22.3%, 26.1%, 21.2%). Also of note, Sara described environmental stimuli more frequently (67, 141, 190, 150) than Osiel (26). The discrepancy in relative frequencies is important as it suggests that although social elements are substantively important, environmental stimuli become increasingly salient in prompting and

[32] The common colocation of tacts with intraverbals is for good reason. Given the ebb and flow of common conversations, it would be atypical, but not unheard of, for someone to simply describe something in the environment without being in conversation with someone else.

facilitating makerspace engagement, especially for students with less positive interactional history with maker tools and CS investigations.

The Consequences

The central role of social interactions becomes even clearer in the frequency of contingencies. Even for less talkative Osiel, 79.8% of his interactions resulted in purely social consequences and 20.2% in social and physical consequences. This discernible preponderance of social consequences corroborates the core premise of behaviorism and other learning frameworks, such as Vygotskian constructivism, that language undergirds complex human behavior and that social interactions are important to knowledge construction.

Limitations

Given the complexity and diversity of topics addressed, including computer science learning in a makerspace environment, the varied interobserver agreement rates are not surprising. The high rates of agreement for the identification of common VB types, echoics, mands, intraverbals, and tacts attest to their functional recognizability and relative decontextualizabilty. In future, targeted training of novel terms, such as computer science and maker tools, may improve inter-rater reliability, the disaggregation of behavior presented can be considered credible, dependable, confirmable, and consequently transferable (Hays & Singh, 2012c). It should be noted that inter-rater comparison is oft actively discouraged in phenomenological and related 'researcher as tool' qualitative studies owing to the uniqueness and importance of the observer's discrimination training, even more. Also, pre-developed taxonomy for relational frames may facilitate their identification.

Conclusion

The behavioral phenomenological picture painted here of novice experiences may be improved with a refinement of researcher focus and closer examination of more specific questions. In this initial behavioral phenomenological investigation of novice behaviors in a makerspace, not every aspect of behavior could reasonably be evaluated. Consequently, not every detail was captured. Nonetheless, the data presented here provide an important first step in behaviorally understanding and articulating the makerspace phenomenon and related attempts at broadening computer science education. In essence, this study aimed a behavioral telescope at a foreign planet and roughly illuminated the contours of a previously behaviorally unexamined landscape. Similar to wearing a headlamp on a dark trail, this approach has not revealed everything, but it has revealed important contours and paths for future exploration.

CHAPTER SIX: DISCUSSION

> "But problems can be solved, even the big ones, if those who are familiar with the details will also adapt a workable conception of human behavior."
>
> B.F. Skinner (1974, p. 276)

The maker initiative is widely promoted as a pathway to remedy underrepresentation of student populations, such as females, in CS and other STEM fields (cf. Buechley, 2013). Similarly, the education community is seeking to broaden CS participation. Given the problematic underrepresentation of certain populations in CS (e.g. Ericson, 2016), parents, community activists, and CS educators are also looking for approaches, such as maker activities to broaden participation (cf. B. DiSalvo, Reid, & Roshan, 2014). As maker and CS initiatives often overlap in goals for knowledge, ability, and learning trajectories, it is unsurprising that makerspace-related initiatives are seen as promising pathways for bolstering CS participation (cf. Brady et al., 2016; Scott, Martin, McAlear, & Madkins, 2016).

If underrepresentation in CS is of pressing societal concern, then CS initiatives would be well served by the application of the science of behavior (cf. Drash & Tudor, 2004). Unfortunately, many makerspace and CS education proponents are uninformed and misinformed regarding behavior analysis (Todd & Morris, 1983b). to date, there have been no identified behavioral investigations of makerspace interventions and novice CS behaviors in such spaces (cf. Davis & Mason, 2016; Perkins et al., 1986). this study was intended to provide an initial, exploratory *behavioral phenomenological* analysis of novice behaviors in a makerspace that may help to better inform future investigations of makerspace effects of novice CS students (cf. Lahren, 1978; Leigland, 1989; McCorkle, 1978), which this author would contest it may.

Contextualizing Non-Experimental Functional Analyses

In this study, the researcher used a *descriptive* rather than experimental approach to the functional analysis of behavior (cf. Groden, 1989). More specifically, a behavioral phenomenological approach was leveraged so as to behaviorally capture interactions within the makerspace as experienced by the participants (Day, 1969).

The behavioral phenomenological approach was first suggested by Willard Day (1977) and developed by students at the University of Nevada at Reno (Lahren, 1978; Mascolo, 1986; McCorkle, 1978). However, many current day behaviorists are less familiar with "the Reno method." Therefore, it is beneficial to make adaptations to better situate behavioral phenomenological studies. This study has added to the behavioral phenomenological approach including the presentation of findings and use of inter-raters in order to make the research more palatable to behaviorists and non-behaviorists.

In keeping with the origins of behavioral phenomenology, this study leverages radical behaviorist approaches to discuss topics, here makerspaces and computer science education, which are not commonly addressed by behaviorists (McCorkle, 1991). Additionally, this study incorporates elements of an intra-behaviorist nature. Relational frame theory (RFT) facilitates and operationalizes discussions of identities and their effects on learning. However, any discussion of RFT presented here might be considered verbal and epistemological shorthand for elaborated discussions of equivalence classes (e.g. Sidman, 2009) and meta-discriminative stimuli (cf. Frankel & Rachlin, 2010).

Though the findings are not completely disaggregated, they do provide much of what this researcher had intended to accomplish – namely, to provide a phenomenological picture of the behaviors emitted by novices in a makerspace. The findings from this investigation are intended to identify worthwhile foci of investigation for radical behaviorist and non-behaviorist researchers alike. As such, the findings may contribute to behaviorist understandings of learning in makerspaces as well as providing added detail to the literature of makerspaces and related, i.e., constructionist, learning and support the improved design of makerspace-oriented instruction and instructional environments.

Summary

Owing to prior discrimination training, the researcher had predicted that physical interactions with the environment would most substantively define and control novices' experiences in the makerspace environment. Looking at Osiel and Sara's behavior certain patterns become evident.

The full day transcripts affirm the interactional histories discriminated from the interviews (cf. interview example of Sara's sister fixing a video game). The confirmation of the interview findings by discrete conversation analysis highlights the utility of the behavioral phenomenological approach for defining further experiments. The revelation of previously unarticulated behavioral patterns occurs more readily with a trained discriminator in a naturalistic environment, such as a makerspace, rather than in controlled experiments. Although controlled experiments provide necessary validation for hypothetical assertions, they will rarely suggest novel approaches or directions (cf. Kuhn, 1962).

This discrimination of complex patterns by a trained observer is comparable to the complex patterns quickly discerned by practiced *Go* players – which, are exponentially more varied, than the smaller set of moves possible in chess (Burmeister & Wiles, 1995).

Family Histories of Making

For Sara, her family's history of making, her own making, and technology had been brought into explicit coordination through her sister's soldering of games, her brother's construction of game artifacts, and programming of games at school – which had been brought into coordination with CS. Sara's relation to CS also presents a transitive relationship, combinatorially primed for the reinforcement of making in a frame of coordination with CS.

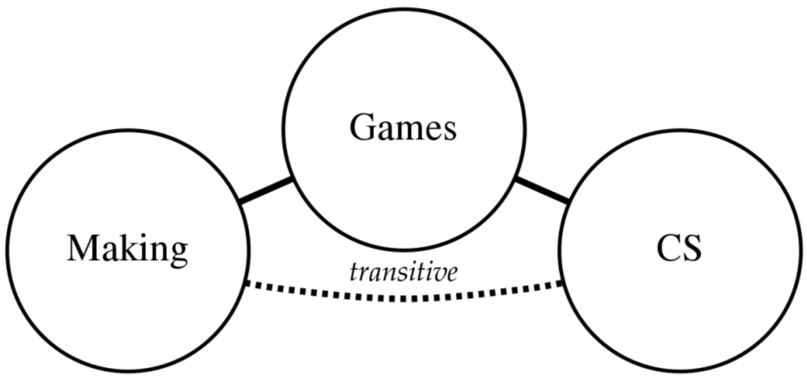


Figure 68. One example of Sara's relation to CS and making via Combinatorial Entailment. This diagram illustrates observed direct relations between making and games, games and CS, and a relationship derived through the transitive property between making and CS.

These findings highlight the exponentially compounding effect of prior conditioning and extent RFs (i.e. conditioned meta-discriminations) on CS and making participation as well as the cumulative, self-reinforcing nature of the interest cycle. The additive and multiplicative effects presented here suggest the importance of involving students and their peers, or peer-proxies, as well as organic opportunities for students to mentor and be mentored.

The value-altering effects of the environment, especially including the availability of social reinforcement, may be seen in the increased fluency of verbal responses relating to maker tasks. For example, technical fluency and concomitant VB can be seen in Sara's emission of specific technical language. Sara's fluency, or 'recall,' of technical terms and processes, in contrast to that of others, illuminates her likely greater susceptibility to social contingencies afforded in the makerspace.

By contrast, Yesenia's behaviors suggest a possibility, though slight, of greater reinforcement though physical or environmental contingencies. Other factors must be considered: as Yesenia's previously articulated history of attending 'sit and get' style lectures in New York indicates that her attendance of extra-curricular classes is automatically or negatively reinforcing.

In interviews, David had evidenced interactional histories connected to making, technology, and CS, though David did not seem susceptible to the social contingencies afforded at the makercamp. In interviews, Osiel had not discriminated much previous interactional history or social reinforcement in relation to making and CS. By contrast, Osiel had noted experiencing aversive responses to his self-technology relations at home. Though Osiel continued with the task on the first day of makercamp, he did not identify social reinforcers at the makercamp.

Lili articulated some prior interactional history with technology, CS, and making. She described being in a frame of coordination with her brother and being in a frame of distinction, especially with regard to technology, from her parents. Lili's articulated frame of distinction from her parents quite likely served as an MO for susceptibility to reinforcement through STEM and making related contingencies.

Antecedents and Relations to Behavior

Analyses of pre, between, and after makercamp analyses highlighted differences in Osiel and Sara's interactional histories. Osiel indicated that his family and friends had little interest in CS and making. By contrast, Sara provided multiple discussions of her family's affinity for making. She also described her and her friends' interests in programming. These differences were reflected in engagement at the makerspace, which confirmed the interview findings. Moreover, the observed verbal behaviors may even hint at causal antecedents unearthed in interviews.

The Role of Technological Habituation

Prior to the makercamp, Sara had a noted self-articulated history of interactions with making and CS as well as attests interests to both, i.e., susceptibility to related contingencies of reinforcement. Certainly, habituation to member tools and maker process facilitated her independent engagement, namely, her Spinosaurus project, at the makerspace (cf. C. L. Hull, 1934).

However, Sara's familiarity with tools only represented one aspect of the contingencies maintaining her engagement. For example, both Sara and Yesenia were given Raspberry Pis to take home at the end of the makercamp. Although, both students noted interest in the Raspberry Pis when leaving the makercamp, the technology, or technological interest, was insufficient motivation, and there was too little behavioral momentum or impetus to continue maker-like investigations of the Raspberry Pis outside of the social context of the makerspace.

The Complementary Social and Physical Nature of Makerspace Learning

Looking at the behavioral progressions before, during, and after the makercamp, it became evident that social and physical aspects of the makerspace are not cleanly separable. The social environment provided the nutrient base for growth of Sara's maker repertoires, but the environment and its tools shaped her growth. Both the social and physical environments supported and developed Sara's extant, although fledgling, maker and CS repertoires. Osiel's experience was different. Interview analyses suggested that interactional histories and resultant framing that would be less conducive to makerspace engagement than Sara's interactional history and resultant relational framing effects.

The maker tasks, programming a Piezo and LED, did provide a hook (cf. Abrahamson et al., 2011) that engaged Osiel with coding, though the 'relatively' open-ended task of programming a buzzer and lights created an aversive situation, Osiel's 'confusion' that he sought to remedy by working on his Morse code program rather than explore the makerspace with others. However, the task did provide motivating circumstances to communicate with others.

Planning for Social and Environmental Reinforcement

Sara's and Osiel's disparate histories, framing, behavioral responses, and maintenance of behavioral trajectories highlight specific and general paths for improving maker-inspired activities building on what might be described as behavioral-constructionist principles.

Osiel was a stranger to the makerspace environment. In order for Osiel to overcome past aversive conditioning and strengthen his self-maker relationship, certain behavioral shaping had to occur at a molecular level. He would have been better served during the makerspace intervention with a thick schedule of reinforcement in the beginning – both task-based and social. He would have benefitted from many smaller challenges at first.

As an example, Osiel and his partner could have alternatively developed code snippets using the navigator-pilot coding method, whereby Osiel would tell David how to code 'A' in Morse code, then David would tell Osiel how to code 'B' in Morse code, or using some other alternation schema. Such alternation between communicator and coder would have resulted in more frequent social interaction. Osiel's habituation to maker tools and programming would increase concomitantly with his susceptibility to reinforcement from maker interventions. Additionally, Osiel's self-maker identity articulations would need to be strengthened contemporaneously. His self-maker relationship responding could be strengthened through conversations that require naturalistically talking about maker projects in relation to his life. For example, he could develop his own automated pet feeder or design his own electronic fashion (cf. Blikstein, 2013; Kafai et al., 2013).

Thinning reinforcement for longitudinal learning. The thinned schedule of reinforcement provided by independent projects was missing for Sara as well when the makercamp ended. In *Mindstorms* (Seymour Papert, 1980) and other constructionist literature (e.g., Blikstein, 2013; Ioannidou, Repenning, Lewis, & Cherry, 2003), proponents of constructionism advocate for personally relevant, independent projects that then support STEM learning trajectories. The reinforcement from these projects, which is not immediately discernible, is the sort of thinned schedule that defines lifelong learning.

Organizing social contingencies of reinforcement. Task completion, finished artifacts, and even the process of creating can be self -reinforcing; although beyond task determinism, the social context in makerspaces is significant (Brahms, 2014; Sheridan et al., 2014). As Seymour Papert (1999; 1980) emphasized, it is crucial to arrange contingencies so that students may display their artifacts in a public space. The public display of artifacts increases the likelihood of social reinforcement of molecular maker behaviors and subsequent molar maker identity behaviors.

A venue for sharing artifacts would support thinner schedules of reinforcement that could better support Sara’s maker and related CS trajectory. Such a thinner schedule is not the nearly indiscernible reinforcement schedule of a ‘consummate’ maker, who only goes to the makerspace once every year or two, but would bolster Sara’s CS and maker molar skill and identity trajectories. Though without experimental control, it is difficult to provide more specific predictions (or inferences) about the schedules of reinforcement that Sara (or Yesenia) would have needed to evoke further tinkering with the Raspberry Pi outside of the makercamp.

Implications for Future Research and Design

As instructional designers, we should leverage the contingencies to which participants are most susceptible, i.e., social contingencies before focusing on other contingencies. The attention given to an intervention should be a function of the control, including value-altering effects that it exerts, for example identity concomitant derived-relational. Further, we should not lose sight of the fundamental interconnectedness of the makerspace experience. Social and physical aspects are like the wheels on a motorcycle – if one is missing, the student will not go far. Special attention should also be given to empirically identifying and measuring how appropriate patterns, thick and thin, of reinforcement can be applied for disparate learners simultaneously in a makerspace without becoming cloying or neglecting students.

Similarly, experimental methods and tools such as the IRAP could be used to measure the strengths of control of various stimuli on students maker and CS related engagement. Also, the IRAP could be used to measure the development of CS-self and CS-maker frames over the course of makerspace-inspired interventions. These IRAP investigations could be couple with attempts to identify the most salient aspects of relational framing needed to strengthen maker and CS-related identity.

The results presented in this dissertation do not sufficiently evaluate the extent of ‘here-ness’ or ‘there-ness’ in participants’ makerspace verbal behaviors and their relationship to participants’ engagement and relational frames; that is, researchers could examine to what extent the relative and total ratios of makerspace related and unrelated statements reflect engagement and implicit affinity for CS and makerspaces.

The analysis of learning trajectories and identity building by verbal behavior type raises questions: How does the extended tacting of maker-related stimuli not present in the environment relate to implicit maker identity? How does the rate of echoics relate to becoming part of a community? To what extent are echoics a function of verbosity and to what extent are they a function of novice identity trajectories?

Revisiting Behavioral Phenomenology

The behavioral phenomenological method can support the identification of novel and worthwhile elements of pedagogical practice to explore. Times have changed since behavioral phenomenology was first introduced by Willard Day in 1977. These changes make behavioral phenomenology an even more viable heuristic than before. Advances in technology, including the ability to more quickly analyze and visualize patterns in behavior, can make behavioral phenomenology more relevant to non-behaviorists.

This study has made adaptations to behavioral phenomenology to make the research and findings more palatable to behaviorists and non-behaviorists alike. Conceptually, the incorporation of relational frames has helped and can further help with operationalizing and discussing complex, non-discrete phenomena such as identity. The use of inter-rater reliability scores can help situate behavioral phenomenological investigations as more than the discriminations of one researcher, while maintaining the scholarly honesty of *epoché*, identifying researcher's behaviors and its antecedents. Also, the identification and analysis of behavioral patterns using common verbal behavior terms, *mand*, *tact*, *echoic*, and *intraverbal*, not only connects behavioral phenomenology to utilitarian applied behavior analysis, but can support the advancement of the science of behavior, as the discrimination of discrete elements has moved other sciences forward as well.

Behavioral phenomenology is particularly well -suited for researching emergent approaches, such as the synthesis of radical behaviorism and constructionism presented here. Behavioral phenomenological investigations can help better illuminate the mechanisms and pathways of constructionist learning and identity building. The resulting behavioral-constructionist insights can then be used to behaviorally bolster constructionist environments such as makerspaces, as well as incorporating constructionist elements in the teaching and research of human behavior, i.e. *shaperspaces*.

Recommendations

In future, facilitators of makerspace activities should purposefully create opportunities for participants' making to occur in coordination with identified reinforcers. Success, i.e., maker-identity growth, could then be measured more authentically by assessing participants' stated preference for making in makerspace and extra-makerspace contexts, controlling of course for data collectors as signals, i.e., discriminative stimuli (S^Ds), for maker-'positive' verbal behaviors (cf. DeVane & Squire, 2008). Tools such as the IRAP, which may be less susceptible to data gatherers as S^D may prove more reliable for measuring preference (cf. Kavanagh, Hussey, McEnteggart, Barnes-Holmes, & Barnes-Holmes, 2016; McKenna, Barnes-Holmes, Barnes-Holmes, & Stewart, 2007).

The identification of the most efficacious and resilient relations as well as the modality of those relations, such as verbal rule-governed behavior, or contingency-derived behavior, whether physical, social, or hybrid, could substantively assist educators in the design of learning environments to bolster nascent CS identities. Makerspaces and maker activities afford several of the most commonly discussed social and embodied pathways to supporting CS interest. Such activities are frequently very social with substantive hands-on physicality that builds on students' extant interests, and, as such, on students' previous histories of reinforcement.

Limitations and Delimitations

This study is neither longitudinal nor large in nature. Rather than attempt to provide statistical significance (Gigerenzer, 1998a, 1998b, 2004), this study is focused on empirical and logical rigor (Horner et al., 2005). This exploratory study is designed to provide a nuanced, fine-grained exploration of purposively selected participants exemplifying the characteristics of those students that makerspace-informed instruction is hoped to benefit most. Namely, participants came from populations underrepresented in CS and were novice makers unfamiliar with the maker movement. The focus on a small number of participants is in keeping with other behavioral–phenomenological studies that emphasize study design and close examination of purposively selected participants (e.g. Lahren, 1978; Mascolo, 1986; McCorkle, 1978). The participants are qualitatively different from experienced makers; namely, they have different interactional histories and are likely susceptible to different contingencies of reinforcement than makers who have previously participated in makerspaces.

As this study is not longitudinal, it does not examine long-term participation in a makerspace by experienced makers; rather, this study is targeted towards supporting instructional design decisions for those unfamiliar with makerspaces. Subsequently, this study focuses on the initial interactions of novices within a makerspace in order to identify those elements that may best support classroom instruction and other shorter makerspace and makerspace-informed educational activities. considering the organization of makerspaces and makerspace-informed activities, the focus of investigation and unit of analysis should not be longitudinal, but rather, should focus on informing the adaption of maker activities to other contexts (Halverson & Sheridan, 2014).

The time allotted for this observational study is common to nonprofit and for-profit makercamps that may last days or up to two weeks. In particular, this study focused on the initial interactions of novices in maker environments as such interactions are much more relevant to designing instruction to support nascent maker identities for novices than examining the interactions of experienced makers over time would be.

It is doubtful that inter-raters can have equal amounts of lifetime discrimination training. For content specific behavioral studies such as this study, behaviorally grounded inter-raters may need extra training in content area terms. For example, although interest in broadening CS and making has grown rapidly in the last few years, relatively few behaviorists are familiar with programming and makerspaces (cf. Escobar & Pérez-Herrera, 2015).

Concluding Remarks

This study is in that it provides a behavioral articulation and basis for key components of education as promulgated by non-behaviorists. Rather than unearth hidden secrets to broadening CS participation, this study reinforces key tenets of constructivist, constructionist, and behavioral approaches to learning and teaching. Similarly, this study highlights how understanding key tenets of behaviorism may support instructional designers and researchers less familiar with advances in behaviorism and relational frame theory.

Revisiting the Determinants of Behavior

Skinner (1974b) identified the three primary determinants of behavior as: the organism's prior experiences, the current situation, and that organism's susceptibility to the contingencies of reinforcement discernible in the environment (See Figure 68).

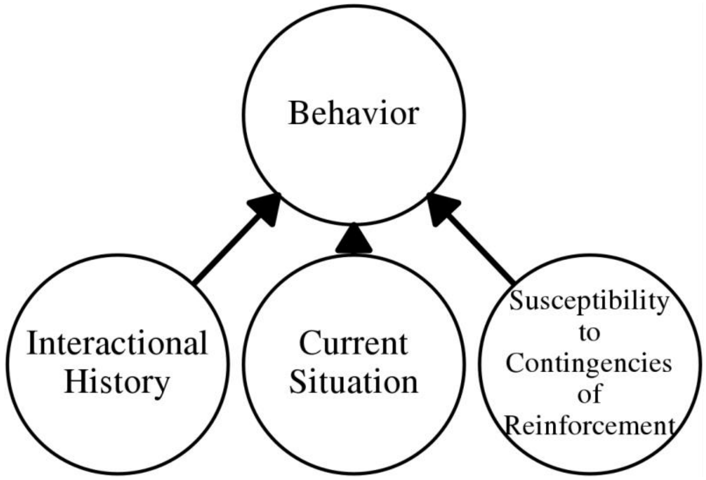


Figure 69. Determinants of behavior. This diagram illustrates the three Factors that B.F. Skinner indicated determine behavior at any time: prior conditioning (interactional history), the current situation, and genetic predispositions.

This study first analyzed students' descriptions of their experiences and those of their friends and family with CS, technology, and making. Then, the two participants exhibited the most disparate prior interactional histories, were selected for closer examination: Osiel, who articulated the least developed CS and making conducive identity, and Sara, who articulated the most likely CS and making conducive identity.

The effects of their prior histories on their makerspace experience were both apparent and not apparent. Osiel spoke less and did not return the next day. Sara spoke quite frequently, attended all four days, and engaged in an independent, creative maker project. Similarities between participants' interactional histories and their subsequent makerspace engagement were readily identifiable.

Perhaps more noteworthy, Osiel and Sara's conversation flow followed similar patterns. The relative percentages for components of verbal behavior were markedly similar. Given the strong discrepancies in their personal histories, the shared similarities in the flow of conversation were most likely attributable to their current circumstance, the makercamp, their phylogenetic predisposition, i.e., how people as social organisms communicate, or behavioral patterns shared across a broader context, such as the cultural mores of US (or Texas) teenagers. Regardless, these findings highlight a pattern that can be leveraged to influence much larger groups of participants: humans, US teenagers, attendees of similarly constructionist-grounded makercamps. Data from this study highlight the significance of social and physical factors.

Social Context Matters

The social environment provides the necessary structure for learning to happen at a makerspace. The social environment provides the nutrient base for learning to grow. Tools alone cannot provide a makerspace or make learning happen. *But tools are important.* Tools provide a hook, a purpose, a context for people to gather and construct knowledge and artifacts. Tools shape the forms learning assumes, much like a trellis for ivy. The utility of tools for learning is ultimately determined by their social affordances, their ability to create and maintain narratives, rather than their physical or technical affordances.

Interactional histories matter. The lives of students that occur and have occurred outside of the makerspace influence what happens in the makerspace. Students' susceptibility to reinforcement from maker-initiatives will be determined by how they relate to makerspaces, makers, and CS. If makerspaces and making are to be utilized effectively to broaden CS participation, it will be necessary to purposefully design learning trajectories for identity behaviors as well as conceptual skills.

Although the underlying import of the findings presented here might not seem out of place in socio-cultural texts discussing Vygotsky's constructivism or situated learning, these findings are novel as they provide a behavioral articulation and identification of the social situatedness of learning in makerspace contexts. Developing further, refined investigations of the interplay of how social and physical elements influence molecular and molar, interwoven and competing learning and identity behaviors can help provide more pragmatic, socially just, and reproducible approaches to broadening CS education and supporting underserved learners in other fields.

In behavioral terms, culture refers to a larger pattern of behaviors exhibited by a verbal community, which is identifiable by shared and mutually reinforcing ways of communicating. People who share a culture have shared behavioral repertoires owing to similarities in their lived experiences, including exposure to societal rules and super ordinate signals. This study has highlighted the importance of molar and molecular components that can add up to create a culture. At the forefront are students' varied identities and how they inform interactions with the social and physical aspects of their environment. In future, we as educators and researchers can better serve the students most in need of our help by acknowledging the interplay of social and physical factors and conscientiously research and design behaviorally articulated, socially grounded approaches to actively support and shape the development of CS and other academic identities.

> "A way of life which furthers the study of human behavior in its relation to that environment should be in the best possible position to solve its major problems."
>
> B.F. Skinner (1974, p. 276-277)

APPENDIX A – Camp Materials

A1. Activity timeline for the makercamp.

Makercamp Activity Timeline: For all makercamp attendees			
	Day	**Activity**	**Approximate Time Allotted**
First Weekend	One	Sign-in, Introduction	15 Minutes
		Instructor-led, group discussion and brief introduction to the history of maker spaces and the local maker space in particular.	1/2 hour
		Participants discussed Raspberry Pis, Linux, and programming languages	1/4 hour
		Participants set up Raspberry Pis [Includes Q&A]	1/2 hour
		Guided programming with GPIOs, Scratch, and PiBrella	1/4 hour
		Morse Code Name [LED] & Piezo Song Challenge	1 hour
		Free Selection	1 hour
		Debriefing and clean-up	15 minutes
	Two	Introductions, sign-in, discuss camp itinerary	15 minutes
		Discuss extant Raspberry Pi projects & RPi Add-ons	1 hour
		Introduction to stepper motors and switches with Pibrella	1/2 hour
		Plan program with switches, LEDs, and motor	15 minutes
		Construct in pairs program with switches, LEDs, and motor – PiBrella.	1 and 1/2 hours
		Free Selection	1 hour
		Debriefing and clean-up	15 minutes
Second Weekend	One	Introductions, sign-in, discuss camp itinerary	15 minutes
		Introduction to circuits, breadboards, and PiCobbler	½ hour
		Guided activity with PiCobbler, Scratch GPIO, and breadboard	1 and ½ hours
		Plan and begin independent GPIO + breadboard project	
		Free selection	1 hour
		Debriefing and clean-up	15 minutes
	Two	Introductions, sign-in, discuss camp itinerary	15 minutes
		Introduction to RPi.GPIO in Python	1 hour 45 minutes
		Independent Python GPIO challenge – convert old program to Python or develop new Python	1 hour 15 minutes
		Free Selection	1 hour
		Debriefing and clean-up	15 minutes

A2. Banner from makercamp related materials

A3. Data Collection Timeline

Phase	Types of Data	Data Collection Processes
Before Makercamp	Audio data, Video data, CS relational diagrams	1. Students were interviewed regarding their perceptions of CS, making, and self in relation to CS, making, and related phenomena. 2. Students drew a deictic diagram illustrating their relations to making, CS, CS careers, friends, family and other interests.
Makercamp Weekend 1	Audio data, video data	1. Students were filmed in interaction with maker activities.[33] 2. The researcher debriefed with a behavioral analyst to discriminate observed behaviors, functional relations, and potential antecedent conditioning.
Between Makercamp Weekends	Audio data, Video data, CS relational diagrams	1. Students were interviewed regarding their perceptions of CS, making, and self in relation to CS, making, and related phenomena. 2. Students drew a deictic diagram illustrating their relations to making, CS, CS careers, friends, family and other interests.
Makercamp Weekend 2	Audio data, video data	1. Students were filmed in interaction with maker activities. 2. The researcher debriefed with a behavioral analyst to discriminate observed behaviors, functional relations, and potential antecedent conditioning.
After Makercamp	Audio data, Video data, CS relational diagrams, Behavioral 3rd party synopsis	1. Students were interviewed regarding their perceptions of CS, making, and self in relation to CS, making, and related phenomena. 2. Students drew a deictic diagram illustrating their relations to making, CS, CS careers, friends, family

[33] Filming is common to 10bit works. Many camps and activities have been filmed. Video recording is focused on the six primary participants; however, incidental filming of others is to be expected and consequently video and audio waivers were required of other camp participants.

		and other interests. 3. External behavioral-phenomenological analysis of transcript elements discriminated by primary researcher as significantly salient to the study. 4. Member-checking by participants of discriminated interactional histories and potential behavioral relations, including relational frames and derived relational responding. 5. Researcher synopsis generated by third-party behavioral advisor evaluating discussions between researcher and peer debriefer.

APPENDIX B – Interobserver Training Materials

B1. Behaviors to discriminate

The following is the handout initially provided to behavior analysts as part of the training component for developing interobserver agreement. The list of references provided with the handout has been omitted. It should be noted that some of the guidelines visible here reflect data that has been omitted from the dissertation format.

Behavioral phenomenological analysis of interviews

Thank you for agreeing to review archival data in order to bolster the qualitative-behavioral validity of “Novice Behaviors in a MakerSpace.” In essence, you are being asked to provide very brief descriptive behavioral analyses (Bijou, Peterson, & Ault, 1968), which might also be described as a “pre-treatment” functional analysis (Groden, 1989), in the style of Day (e.g., Day, 1977) and McCorkle (1978) among others (e.g., Dougher, 1989; Leigland, 1989). These brief FBAs may differ from the FBAs to which you are most familiar. Here, the intent is to rely on your previous discrimination training to discern (likely) functions of behavior in “natural” environments without conspicuous experimental construction. Namely, conditions vary (semi) “naturistically” with the environment rather than explicit control/experimental groups and conditions. You are being asked to discriminate functions (and types) of behavior in a behavioral-phenomenological manner providing your discerned functional behavioral analysis. Namely, you are being asked to discern contingencies controlling behavior reliant substantively on your own prior discrimination training (McCorkle, 1978, p. 53) and identify potential relational frames and derived relational responding, especially with a focus on deictic and other potentially identity related relational frames.

The interview and other behaviors to be analyzed are behaviors discriminated (by the primary researcher) as most salient to the discussion of CS and maker related identity and skills trajectories. Before beginning the (Day and Leigland guided) functional analysis of behaviors, you are asked to successfully complete a training instrument that verifies your proficiency in the articulation of the concepts most salient to the current investigation, i.e., proficiency in describing behavioral phenomenology, relational frames, and in behaviorally articulating "identity" and "embodied cognition." [In short, the training assessment is much like an open-ended essay assignment that can be resubmitted until all answers are deemed correct/sufficient.]

Classes of Behavior to be Discriminated

Although comparable past behavioral phenomenological research did not engage in a "hypothesis testing venture[s]" (cf. Patterson, 1974, p. 901 as cited by Lahren, 1978, p.65), emphasis has been given to selected target behaviors. Here, the selected target behaviors sought for discrimination, which may overlap, were broadly:

1. Identity related behaviors. Many of a number of molecular (micro) behaviors constituting larger, more longitudinal molar (macro) behaviors and response classes relating to or describable as identity and identity frames (Dymond & Barnes, 1994, 1995; Stewart, 2013). The discrimination of identity relevant behaviors was significantly dependent on the researcher's previous discrimination training (Hays & Singh, 2012; McCorkle, 1978). Also, special attention should be given to self-referential statements, i.e., statements with "I" and "me" (cf. Fies & Langman, 2011).

2. Embodied cognition. As commonly understood, "cognition" cannot be readily observed (or discriminated from other behaviors), regardless through which epistemological lens it is articulated (cf. Skinner, 1984). Here, the observer will make note of (seemingly, potentially)

physically grounded behaviors (both verbal and non-verbal). This will require explicit, elaborate description of behaviors, the physical environment in which they occur, and the intersection of the two (McCorkle, 1978, p. 61). Moreover, the analyst should attempt to identify and code behaviors (in both modalities) as epistemic and pragmatic actions.

a. Epistemic actions [problem-solving] – Kirsh and Maglio (1994) define epistemic actions as “actions performed to uncover information that is hidden or hard to compute mentally” (p. 513). As such, epistemic actions will be operationalized as actions (physical movements) without an obvious physical consequence, e.g., hand gestures, arm movements, physical shifts (potentially sharing topographical similarities to programming interactions). Gestures, particularly, exemplify interaction (movement) in a physical space to facilitate problem solving (e.g. Cook & Tanenhaus, 2009; Kirsh, 1995; Lozano & Tversky, 2006) without bringing the agent physically closer to accomplishing a goal (cf. Skinner, 1984).

b. Pragmatic actions [physical task accomplishment] – Kirsh and Maglio (1994; 1996) describe pragmatic actions as “actions whose primary goal is to bring the agent physically closer to his or her goal” (p.515), e.g., grasping a bottle of Yoohoo and bringing it to one’s mouth. [Although not identified in behaviorist literature, the epistemic-pragmatic dichotomy aligns well with behavioral concerns when articulated as pragmatic (i.e., with an observable, physical consequence bringing the target physically closer) and non-pragmatic (i.e., the gesture (movement) has no readily identifiable consequence on the physical environment. It may be used for communicative purposes with one’s self (hard to discern) or others).]

3. Relational framing – The analyst should attempt to discriminate evidence of (potential) relational frames. This discrimination will (most likely) only be tractable for verbal behaviors. Special focus will be given to identifying relations articulated by participants regarding STEM

components (e.g. programming), “making”, STEM practitioners (e.g. programmers, computer scientists), “makers”, potentially self/identity related components (e.g., family, hobbies, etc.), and other potentially relevant references (cf. Cuero & Kaylor, 2010; Johnson, Brown, Carlone, & Cuevas, 2011; Zambrana & Zoppi, 2002).

Moreover, special attention should be given to those deictic relations evidencing characteristics of a phenomenological, *noetic* relationship (Ihde, 2012, p. 26; cf. Moustakas, 1994, pp. 31–32). Namely, verbal behaviors illuminating how the participant is (qualitatively) experiencing an experience will be noted. [If such possibly noetic behavior is observed, additional attention will be given to discussing caveats and concerns with referencing private events, especially in regards to relational frames (cf. Hayes, White, & Bissett, 1998).]

B2. Embodied and Relational Behavioral Analyst Assessment

The following text was used as a training document for inter-raters prior to transitioning to Survey Monkey for interview coding and Excel documents with pre-defined selection possibilities for the coding of verbal behavior. The references provided with this document have also been omitted.

Please answer these questions as you are able. Expand as necessary [i.e., answers need not be limited by space provided].

1. Briefly articulate the differences between Leigland's (1989) Functional Analysis of Verbal Behavior and more common approaches to the functional analysis of behavior (FBA) (e.g., Mayer et al., 2014a; Miller, 2006; Vargas, 2013b).

2. "Embodied cognition" is not commonly discussed in the verbal community of behavior analysis. Briefly define, preferably in behavioral, functional-analytic terms, "embodied cognition" (e.g., Anderson, 2003b; Chemero & Silberstein, 2008). Additionally, Kirsh and Maglio (1994) have defined *epistemic* and *pragmatic* actions. Briefly differentiate these two terms (preferably in functional terms) and describe how they might be discriminated.

3. Briefly explain equivalence classes and behaviors relating to such (e.g., Sidman, 2009).

4. Please give an example of derived relational responding (e.g., S. C. Hayes, Fox, et al., 2001; Leigland, 1997).

5. Explain *identity* in behavior analytic terms and potential (non-mentalistic) behaviors that may be discriminated relating to identity (also "self") (Dymond & Barnes, 1994, 1997; McHugh, Barnes-Holmes, Barnes-Holmes, Stewart, & Dymond, 2007; Phelps, 2015; Stewart, 2013).

6. Briefly describe the following (cf. S. C. Hayes, Fox, et al., 2001):
    a. Mutual entailment
    b. Combinatorial entailment
    c. Relational frame – coordination
    d. Relational frame – opposition
    e. Relational frame – distinction
    f. Relational frame – comparison
    g. Relational frame – hierarchical relations
    h. Relational frame – deictic relations

B3. Reference sheet for coding of verbal behaviors

The follow information was provided in its current form to assist raters in the coding of data.

In order to provide clearer identification of verbal behavior types for more pragmatic and potentially more informative descriptions of novice behavior in a makerspace, the study has focused on the four most commonly discussed types of verbal behavior, namely the tact, mand, intraverbal, and echoic (REF Skinner; Sundberg; Miller).

Verbal behaviors to be identified (coded) as *mands* are those whereby the speaker makes a request, places a demand, or gives a command. It should be noted that questions are identified as mands as they represent requests for information.

Example: *Give me that LED.*
Non-example: *That LED is really cool.*
Example: *Do you know the teacher, Mr. Jones?*
Non-example: *Mr. Jones is my favorite teacher*.

To be identified as a ***tact***, the stimulus must be present or have been recently in the environment. Consequently, the absence of a stimulus is not a tact. Rather any verbal behavior referring to an absent stimulus could quite likely be the result of prior conditioning and intraverbal control. Additionally, tacts should function to label or describe – rather than as com(mands) or de(mands).

Example: *The HDMI port is on the left side.*
Non-Example: *I have an XBOX at home.*
Example: *My SD card doesn't work.*
Non-example: *I don't have an SD card.*
Example: *Everybody else has an SD card.*
Non-example: *We use Netbeans at school. [Participants are not at school.]*
Example: *I just played Minecraft.*
Non-example: *I played Minecraft last weekend.* [*And Minecraft has not been recently present in the current environment*.]

Intraverbals are influenced by other's verbal behavior, i.e., under stimulus control of verbal behavior. Intraverbals do not share point-to-point correspondence with others' verbal behavior (such behaviors are echoics). Intraverbals commonly reference stimuli and behaviors not currently present. To be qualified as an intraverbal, antecedent VB (likely) exerting control should be present.

Example: *Speaker 1: How are you?*
Speaker 2: Good. [Intraverbal]
Non-example: *Speaker 1: This is great curry.*

	Speaker 2: Please, pass the salt.
Example:	*Speaker 1: Do you know Mr. Jones?*
	Speaker 2: Yes, he's a hard teacher. I almost failed his class. [intraverbal]
Non-example:	<Car drives by.>
	Speaker: Look it's a Ferrari.

Echoics are those behaviors displaying point-to-point correspondence with other's preceding verbal behavior. If a parent says, "apple" and the child says "apple".

Example:	*Speaker 1: GNU stands for GNU's not Unix.*
	Speaker 2: GNU stands for GNU's not Unix.
Non-Example:	*Speaker 1: The scientist who most improved our understanding of behavior was…*
	Speaker 2: B.F. Skinner
Example:	*Speaker 1: operant chamber*
	Speaker 2: operant chamber
Non-example:	*Speaker 1: operant chamber*
	Speaker 2: Skinner box

'Impure' and hybrid VB. During the coding the verbal episodes are labeled by the VB types discriminable by the researcher. Three columns are provided for VB type – a forth hyphenated VB may be added if necessary. The labels are intended to reflect VB characteristics present – rather than being limited to only exact matches. For example, if a speaker were to state "do you like apple sauce?" and the participant replied "apple sauce?!" or "sauce?" the VB would be coded as an intraverbal, as it is under the control of preceding VB, as an echoic as it exhibits point-to-point (or partial point-to-point correspondence, i.e., what might be described as a *sequelic*) with the preceding verbal behavior, and as a mand, as clarification (or explanation) is being requested.

See: http://www.asha.org/Events/convention/handouts/2007/1504_Matteo_Jo-Anne

Appendix C

Appendix C1. Identified Tangible Programming Interfaces

Tangible programming interfaces identified:

- tactusLogic, which uses wooden blocks adorned with clay symbols and pictures to produce output on a screen, designed especially in consideration of schools with limited funds, (A. C. Smith, Springhorn, Mulligan, Weber, & Norris, 2011),
- the Digital Dream Lab, which allows students to program the background and characters in a hybrid virtual space with table-top puzzle blocks (Oh et al., 2013),
- robo-blocks, snap together magnetic blocks to control a robot (Sipitakiat & Blikstein, 2010a; Sipitakiat & Nusen, 2012),
- Toque, designed in collaboration with students, whereby physical sound inputs are mapped to virtual commands for cooking in a virtual environment (Tarkan et al., 2010),
- low cost, low energy foam blocks that control a toy car (A. C. Smith, 2008),
- Marble Track Audio Manipulator, using magnetic marble track sequencing to create songs (Bean et al., 2008),
- Topobo, an electronic construction block kit able to store simple commands to control robot-like objects (Raffle, Parkes, & Ishii, 2004),
- tangicons, an adaptation of Quetzal with wooden blocks to program a robot (Scharf, Winkler, & Herczeg, 2008),
- Dr. Wagon, wooden blocks, some of which are spreadable, for programming a robot, and
- T-maze, a block-based system using multiple sensors to design and escape mazes.

Appendix C2. Common Relational Frames

a. *Coordination*: equivalence class relations (cf. Sidman, 2009), whereby stimulus events are articulated in a relation of “identity, sameness, or similarity” (Y. Barnes-Holmes et al., 2002, p. 106).
b. *Opposition*: given some quality, referents are identified as exhibiting opposite dimensions of that quality. For example, *hot* is articulated as the opposite temperature (quality) of *cold*.
c. *Distinction*: two referents are discriminated as not being the same. For example, observing “This is not warm water,” establishes a simple binary contrast, but no spectrum, that is, it is still unknown whether the water is boiling hot or freezing cold (Y. Barnes-Holmes et al., 2002, p. 106).
d. *Comparison*: This includes many possible relations, such bigger and smaller, faster and slower, better and worse, and more (Y. Barnes-Holmes et al., 2002, p. 106).
e. *Hierarchical*: This may include a broader class of terms, whereby elements are identified specifically in relative proportion to one another. For example, noting that Fred is taller than Willard and Willard is taller than Murray provides no

indication of the measured height of Willard. This is similarly true with spatial, temporal, and other relative descriptors.

f. *Deictic*: relations articulated from the perspective of the speaker (Y. Barnes-Holmes et al., 2002, p. 107; cf. Weil, Hayes, & Capurro, 2011). For example, when a speaker states “I am here,” the terms *I* and *here* are both relative to the speaker.

Appendix D

Appendix D1. Hybrid Verbal Behavior Flow Charts

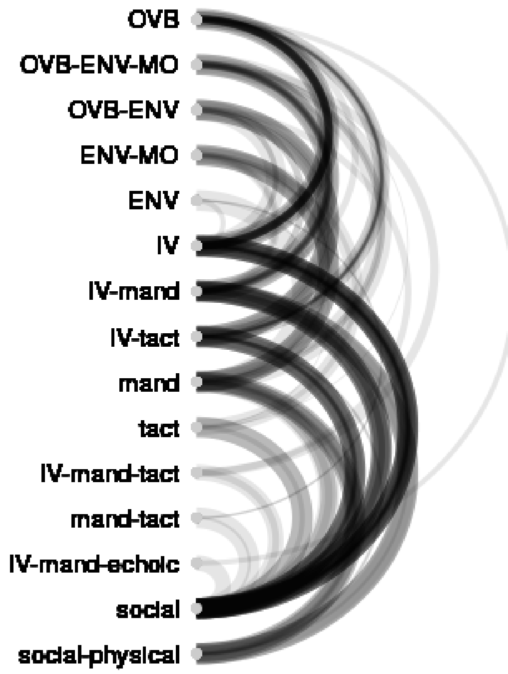


Figure D1. Osiel Day 1 hybrid verbal flow ABC. This figure illustrates the non-disaggregated flow of antecedent, VB, and consequence types for Osiel on day 1.

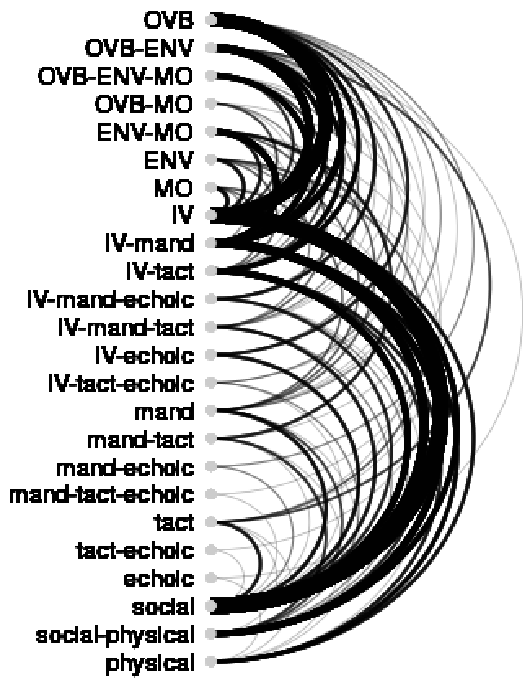


Figure D2. Sara day 1 hybrid verbal flow ABC. This figure illustrates the non-disaggregated flow of antecedent, VB, and consequence types for Sara on day 1.

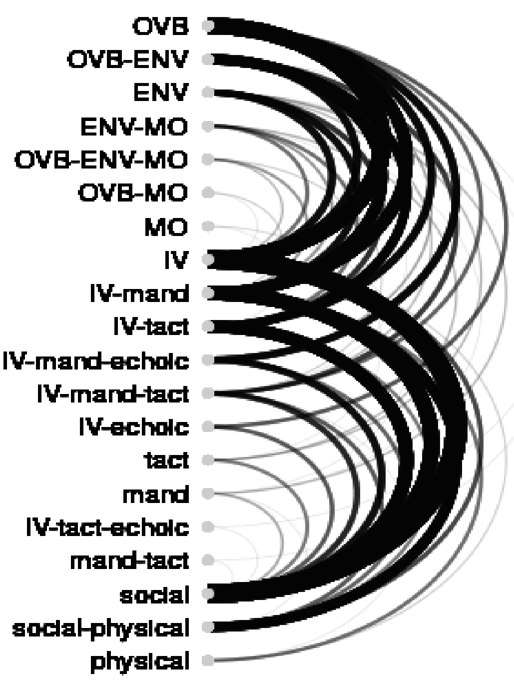


Figure D3. Sara day 2 hybrid verbal flow ABC. This figure illustrates the non-disaggregated flow of antecedent, VB, and consequence types for Sara on day 2.

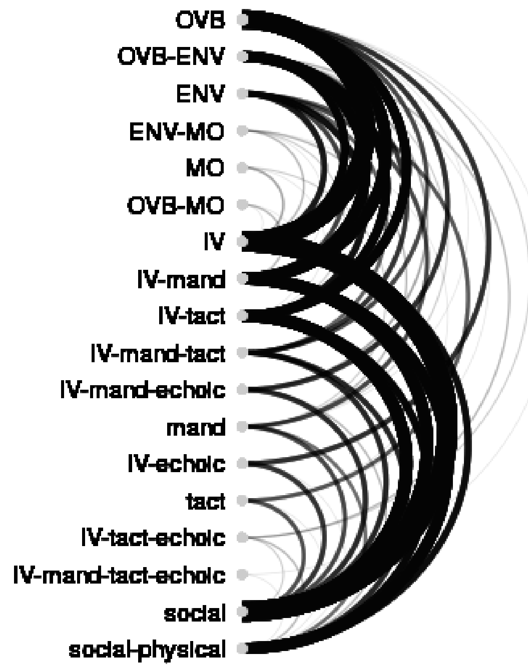


Figure D4. Sara day 3 hybrid verbal flow ABC. This figure illustrates the non-disaggregated flow of antecedent, VB, and consequence types for Sara on day 3.

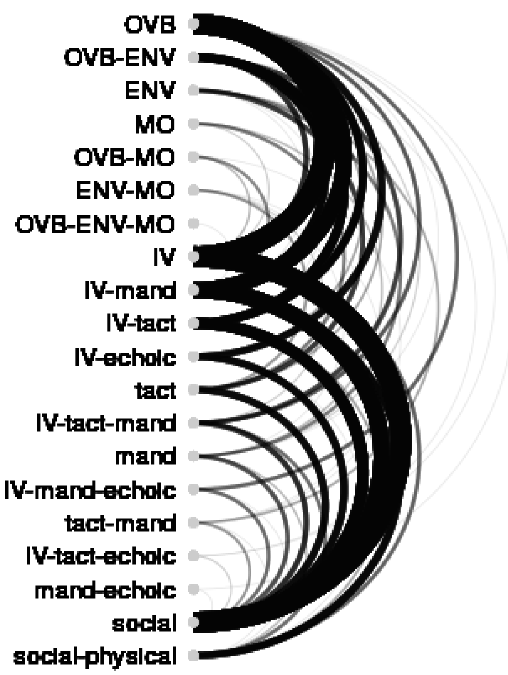


Figure D5. Sara day 4 hybrid verbal flow ABC. This figure illustrates the non-disaggregated flow of antecedent, VB, and consequence types for Sara on day 4.

Appendix E

Appendix E1. Semi-Structured Interview Questions

Informal participation solicitation semi-structured screener:

1. Have you ever been to a “makerspace”?
2. Or, have you ever done “maker” activities such as a makercamp or attended a Maker Faire?

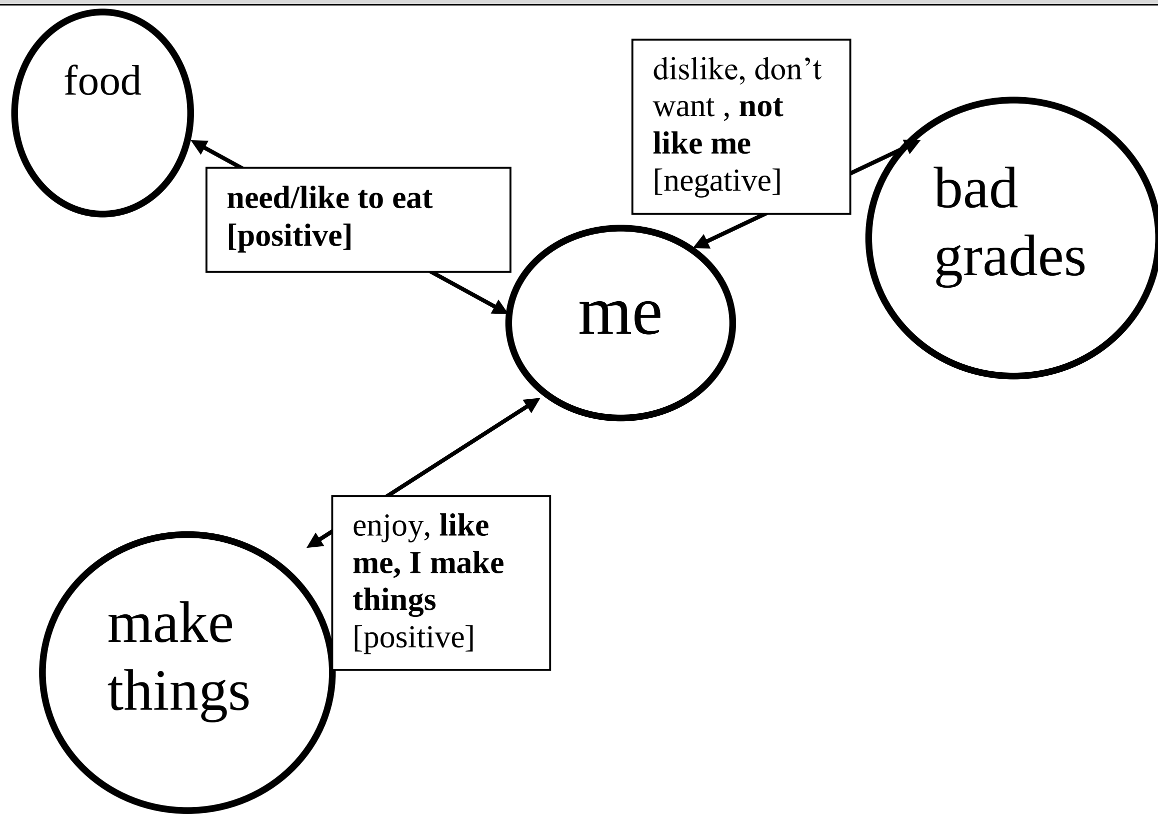
Semi-structured interview protocol: Behavioral Investigation Makerspaces

1. Do you know what a makerspace is? Have you ever attended a makerspace or done “maker” activities?
2. What kinds of people create things with computers? Are you that kind of person? Why or why not?
3. How does making and creating with technology and computers relate to you? To your life? [Could you tell me about a time you made something (with computers)?]
4. What relationships do your friends/family/neighborhood have to making/creating/programming? [E.g. tell me a story about a time when someone you know made something with computers or technology.]
5. What personal history might make someone want to study computers and programming? Do you have that history? Why or why not?
6. What interactions have you had with computers? Programming?
7. Are there any questions you have for me or anything else you think I should know (about making/creating/programming)?

Appendix E2. Self-to-Making Relationship Map

Relationship Diagram Explanation Self-to-Making Relationship Map, page 1 of 2	
1. Draw a circle representing you in the center of the paper. 2. Then draw circles for each of the items listed on the next page. 3. Next, draw lines showing your relationship to those elements. 4. Label the relationship [line] using the labels provided on the next page. 5. Feel free to add any additional circles, connectors, or labels you like.	***Note***: The relationships may be "negative". For example, you may "hate" or avoid doing something. You may even want to write both "love" and "hate". You may choose to not draw a connection. Additionally – please add any connections among circles as you like.

Example:



<table>
<tr><th colspan="2">Draw Your Relationship Diagram Here
Self-to-Making Relationship Map, page 2 of 2</th></tr>
<tr><th>Draw circles for each of these:</th><th>Use these labels [as many or as few as you like - and any others you feel appropriate]:</th></tr>
<tr><td>1. Making things
2. Making things with computers and other technology
3. Programming
4. Tinkering
5. Electronics
6. People who study computer science
7. Nerds
8. My ethnicity
9. Other ethnicities
10. College/University</td><td>1. Like me / Not like-me
2. Like / dislike ; Love / hate
3. Avoid / seek out
4. Need / don’t need
5. Must do / cannot do
6. Ability / no ability
7. Interest / no interest
8. Positive / negative
9. No connection
10. Other:_<describe relationship>_</td></tr>
<tr><td colspan="2"></td></tr>
</table>

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VITA

Don Davis is from Austin, TX. He completed an undergraduate degree with a dual major in English and German with minors in linguistics and Germanic Civilization at the University of Texas at Austin. He also attended Humboldt Universität zu Berlin studying older German literature and computer science. He lived abroad in Berlin for seven years. When Don returned to the US, he taught English language learners. While working with recent immigrants, he founded the 501c3 Recycled Electronics and GNU/Linux used for Education (reglue) in order to support underserved students using computers repurposed with the GNU/Linux operating system.
He then completed a M.Ed. in educational technology in hopes of promoting more equitable and beneficial use of technology in public education. Don's desire to provide more equitable and relevant computational thinking learning opportunities led him to pursue a Ph.D. in interdisciplinary learning and teaching.

In the last few years, his research has taken many forms but with the same end-goal – broadening participation in CS identity and learning trajectories. His research has utilized learning analytics, data mining, qualitative, and behavioral methods. Don is focused on expanding and informing educational practices by building on the science of behavior. His interests and current projects include examinations of makerspaces, identity, the relational framing of computer programing and related problem solving, and the intersection of game-based learning and behaviorism.