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SCIENCE LEARNING IN EVERYDAY LIFE

Scientizing and Cooking: Helping Middle-School Learners Develop Scientific Dispositions

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ABSTRACT: We aim to understand how to help young people recognize the value of science in their lives and take initiative to see the world in scientific ways. Our approach has been to design *life-relevant* science-learning programs that engage middle-school learners in science through pursuit of personally meaningful goals. In this paper, we analyze the case studies of two focal learners in the Kitchen Science Investigators life-relevant, science-learning program. Our analysis highlights ways to design life-relevant science-learning programs to help learners connect science to their everyday lives in meaningful ways. Our findings point to the ways in which learners' dispositions develop, which have implications for the design of programming and learning environments to promote the development of scientific dispositions. © 2013 Wiley Periodicals, Inc. *Sci Ed* **98:**36–63, 2014

INTRODUCTION

Well I've been thinking about being a chef now that I'm in [the] KSI [after-school program]. So I think that would be a really interesting job. . . . Because, okay, if I'm a chef, then most chefs just put ingredients in there, but if I'm a chef, my food'll turn out like exactly the way I wanted it, and it'll probably be even better than I expected because I'll actually think about the way that I wanted it instead of just putting ingredients in there and following a

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> recipe. Like I can change up the ingredients because I'll know what the thickeners do, and I'll know what these types of liquids do. Yeah, so I can change it up to get it the way I want it specifically. — Candyce, Grade 6

Science education has the goal of producing scientifically literate citizens (Rutherford & Ahlgren, 1991) who are able to actively apply science to the world around them. Yet many learners face difficulties connecting science to their everyday lives (Atwater, 1996; Lee & Fradd, 1998). For example, prior to the above excerpt, Candyce, a participant in our after-school program, found science class to be boring and unrelated to her life and had decided that she was not a "sciency" person. However, as she began to recognize the everyday utility of science for tasks such as cooking, Candyce reconsidered her attitude toward science. She commenced to find practical applications of scientific inquiry and used them to achieve her goals. In essence, Candyce was beginning to *scientize* her daily life activities, i.e., to see the world through scientific lenses. Indeed, in reaching our nation's standards of science for all, helping more children develop scientizing attitudes and dispositions is an important endeavor.

Similar to the way mathematics education researchers (Nasir, 2000; Papert, 1980) discuss children's abilities to mathematize their worlds, we define *scientizing* as developing the ability to recognize the relevance of science in practical areas of one's life (e.g., cooking) and in those situations, engaging in its pursuit. Though not an exhaustive list, scientizing involves asking questions about how the world works, searching to understand what is known, recognizing the gaps in one's understanding that need to be filled to accomplish one's goals, and investigating to answer remaining questions. The journey of scientizing is one of curiosity and discovery, and it includes hypothesizing, predicting, observing, measuring, and developing theories along the way (Chinn & Malhotra, 2001; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

Scientizing is not currently the norm for middle schoolers (Chinn & Malhotra, 2001; Lee & Fradd, 1998). But what if it were? Children might use what they learn in science class outside on the playground with friends, at the store with their parents, and at home with their siblings. Middle-school track stars might call upon laws of motion to investigate the most effective gait for a 50-meter race. Young bakers might determine the most appropriate baking dish for perfecting a pound cake through a process of inquiry informed by their knowledge of heat conduction. Learners might then become scientifically literate and engaged citizens, and more might pursue scientific disciplines.

The goal of our research project has been to learn how to help middle-school learners see the relevance of science in their lives, recognize situations in which science might be relevant, ask new questions, and design scientific experiments to build their understanding. We aimed to help learners enjoy the inquiry processes of science so that they would *want* to use these processes in their everyday lives. Our approach has been to design *life-relevant* science-learning programs: environments that engage young learners in science by enabling them to pursue personally meaningful goals that require scientific knowledge and practices for success.

We designed a life-relevant science-learning program called Kitchen Science Investigators (KSI). KSI is designed to help participants learn science in the context of recipe design, and, in the process, participants would ideally come to appreciate the roles of science in their everyday activities. KSI is a life-relevant science-learning program for those interested in food and cooking. Children engage in designing recipes, cooking, and baking. These activities are personally relevant to participants and give them opportunities to experience the usefulness of scientific phenomena and processes in achieving their goals. In this paper, we focus on the case studies of two KSI participants who began to scientize their everyday lives as a result of KSI experiences. We analyze those cases to identify what motivated these learners to scientize, how that scientizing progressed, and the components of KSI that promoted their development. We expect that what we have learned about how to promote engaged participation and scientizing will be applicable to the design of other life-relevant science-learning programs.

BACKGROUND

When learners scientize, they take on new roles that inform, reconfigure, and add new information to the world around them (Calabrese Barton, 2001). They feel empowered to make their world a better place and, in the process, see themselves in new ways. Bereiter (1995) argues that if we want children's learning to go beyond the classroom, we need to help them at a level beyond conceptual understanding; we need to help them develop *dispositions*. The term disposition has been defined in everyday use as "the predominant or prevailing tendency of one's spirits; natural mental and emotional outlook or mood" (Collins English Dictionary, n.d.). Disciplinary education researchers have used the term to mean taking on values of, ideas about, and ways of participating in a particular discipline frequently and voluntarily (Gresalfi & Cobb, 2006; Katz, 1993). Dispositions may develop in one context, but they are often recognized when learners are observed using them in other contexts of their lives (Bereiter, 1995). For example, one recognizes a disposition to scientize when a child applies scientific experimentation used in science class to new questions that arise at home. Our notion of scientizing is congruent with these definitions of disposition; *in essence, scientizing means developing dispositions toward scientific reasoning*.

Developing scientific dispositions is a broad goal that has many parts. Specifically, scholars have emphasized four building blocks to the development of scientific dispositions: (1) conceptual and procedural understanding, (2) interest, (3) social interactions, and (4) personal connections (e.g., Borda, 2007; Gresalfi, 2009; Kilpatrick, Swafford, & Findell, 2001). With respect to science, conceptual and procedural understanding refers to understanding scientific concepts and procedures. It also implies knowing when, why, and how to use them. Interest involves one's desire to engage in the practices of a scientific discipline. Social interactions refer to a learners' engagement with others in scientific pursuits. Personal connection refers to connecting disciplinary practices and knowledge to one's value system and norms. Learners will develop dispositions to reason scientifically only if they have a chance to develop understanding, develop interest, have social interactions that help them to sustain their interests and see the value in what they are learning to do, and make connections between what they are learning and their own lives.

Developing conceptual and procedural understanding (and skills) needed to engage productively in science involves helping learners develop the skills and use these skills often and in the appropriate situations (Borda, 2007; Eberbach & Crowley, 2009; Gresalfi & Ingram-Goble, 2008; Kilpatrick et al., 2001). For example, Gresalfi and Ingram-Goble (2008) express the need to help learners develop procedural, conceptual, and critical understanding in mathematics. This means that learners should have an understanding of *how* to use resources (e.g., tools, technology, operations) in a discipline (procedural dispositions), *when* to use resources based on their understanding of topics and concepts in that field (conceptual dispositions), and *why* one should use particular resources (critical dispositions).

Interest in a discipline requires seeing the utility, relevance, worth, and *coolness* of the content knowledge and practices of that discipline (Eberbach & Crowley, 2009; Kilpatrick et al., 2001). Learners need help pursuing their interests, focusing on topics of interest (Borda, 2007) and exploring new ways to pursue their interests (Barron, 2006). It then becomes important to help learners recognize when their unique ways of engaging in science are indeed forms of science engagement (Clegg & Kolodner, 2007).

Sustaining one's interest in a discipline requires interacting with and working with others (e.g., peers, parents, mentors) who share their interests (Barron, 2006; Brickhouse & Potter, 2001). Lack of positive social interactions around science can often influence learners to be disengaged from the discipline. When learners perceive science to conflict with the values and norms of their home and peer groups, they often disengage from it (Brown, 2006). In addition, learners will face difficulties gaining access to the resources and help needed to scientize when they do not have relationships with family members, peers, or community members who also tend to scientize. On the other hand, learners with close relationships to others who participate in science, technology, engineering, and mathematics (STEM) fields often participate more deeply in those fields themselves (Barron, 2006; Brickhouse & Potter, 2001). Likewise, scientists often have networks of peers and colleagues with whom they interact in formal settings (e.g., the office, conferences) and in informal settings (e.g., meals, vacations) (Eberbach & Crowley, 2009). It therefore becomes important to help learners begin to value and develop relationships with others who are interested and engaged in fields that interest them (Bereiter, 1995).

Finally, disposition researchers call for helping learners develop personal connections to relevant content and practices. This means helping learners develop a depth of understanding about how what they are learning relates to who they are. Bereiter (1995) asserts that in order for learners to use what they learn beyond the classroom, educators must help connect learners' understanding, interests, and social interactions to their value systems and their norms—their identity. Borda (2007) emphasizes the need for learners to understand where science fits in their value system, so that they can apply science to decisions in their daily lives and in society.

While helping learners develop conceptual, interest, social dispositions, and personal connections to science is important in science education, experiences in classrooms tend not to be sufficient for development of scientific dispositions. Conceptual and procedural understanding can be difficult to promote in schools because concepts are often taught in abstract ways or are otherwise divorced from the relevant contexts of their use (Lee & Fradd, 1998). Many learners therefore have trouble connecting what they are doing in science class to scientific inquiry outside of school. In addition, learners often lack the flexibility in school settings to follow their interests and develop personal connections to science. Learners who have been successful at developing interest and personal connections to STEM fields often develop these interests as they move across the ecology of communities, relationships, and resources in their lives (Barron, 2006). These learners tend to develop interests in STEM fields through relationships with others outside of school settings (e.g., home, church, affinity groups). It therefore makes sense that if one wants to promote learners' development of scientific dispositions they must design ways of helping learners develop competence, interests, social interactions, and personal connections related to science that take fuller advantage of the multiple settings of learners' lives.

Existing research provides many insights about how to promote each of the four building blocks of disposition, but less is known about how learners' dispositions develop holistically as these building blocks are integrated across the settings of learners' lives. If we understand how such development happens and what influences it, we can gain insights on ways in which to more systematically promote learners' development of scientific dispositions.

Key to understanding development of disposition is an understanding of interactions between the development of *external* patterns of action and the *internal* motivations that drive those patterns. Dispositions and their development refer to learners' external patterns of activity (e.g., consistency, frequency, complexity, and initiation of action) (Gresalfi &

Cobb, 2006; Katz, 1993). To also understand the development of learners' internal or personal connections to science (e.g., why a concept or practice is important; what it means; how it connects to one's goals; when it's useful, imperative, or abhorrent), we are influenced by *identity* research.

In particular, we draw upon Gee's (2000) "Discourse" identity framework, which defines one's identity as participation in the "Discourses" of their lives. A (capital D) "Discourse" is any combination of views, norms, and ways of being that can cause one to be recognized as a certain type of person (Gee, 2000). Discourses are defined by ways of speaking or writing, acting, and interacting, using one's face and body, dressing, feeling, believing, or valuing, as well as using objects, tools, or technology. Gee defines one's core identity as the trajectory of his or her participation across Discourses over time. This framework is particularly fitting because it helps us to map learners' day-to-day actions with broader Discourses that motivate, inform, and connect learners personally. Drawing upon both identity and disposition frameworks helps us to gain insight regarding what a learner's personal connections to science might be, how they might be developing, and what educators and designers might do to best promote them.

Nasir's (2002) identity, goals, and learning framework provides a basis for our approach to promoting these deep and sustained patterns of interaction through personal connections. Her framework suggests that if we help learners connect science to their personal goals, they will develop more scientific goals. These goals will then motivate the necessary learning for their achievement. As their learning develops, learners will begin to engage with the concepts and procedures and see themselves more scientifically. KSI is therefore designed to engage learners through their personal cooking goals and help them achieve their goals scientifically. We have found that this approach provides a felicitous way of helping learners develop the conceptual understanding, interests, social interactions, and personal connections that disposition research suggests might lead to development of scientific dispositions.

DESIGN OF KITCHEN SCIENCE INVESTIGATORS

KSI sits at the intersection of formal and informal science learning. It is neither science education in a formal setting nor science in everyday life. Instead, it lies between the two. We took an authoritative role in the design of KSI, facilitating activities with intentions of helping participants move their learning productively and meet their personal goals (Clegg, Gardner, & Kolodner, 2010). We used insights from school-based as well as informal learning research and practice to inform the design of KSI's activities and moment-to-moment scaffolding. As in school environments, we needed to ensure an appropriate structure for promoting the kinds of experiences and reflection needed for conceptual and procedural learning (Barron et al., 1998; Blumenfeld et al., 1991; Kolodner et al., 2003). However, we also needed to make sure that participants would have enough of their own personal choices and flexibility required for promoting and sustaining learners' interests, personal connections, and social interactions in the ways needed outside of school (Crowley & Galco, 2001; Crowley & Jacobs, 2002; Falk & Dierking, 2002).

The primary way we addressed these differing needs was to design the sequencing of activities to be relatively structured early on when participants needed to learn foundations such as asking questions, designing experiments, making observations, measuring, sharing results, and drawing conclusions. As learners develop foundational understandings and begin to master these capabilities, activities in KSI gradually become less structured, providing more choice. More structured days, which we refer to as *Semistructured Days*, are designed to engage participants in activities that focus on developing scientific conceptual and procedural understanding in the context of cooking (i.e., what makes foods rise or thicken). Learners and facilitators design experiments as a group that highlight the effects of varying amounts or types of ingredients in a recipe. Learners carry out each variation in small groups. After returning to the whole group, learners share their results, taste their dishes, and draw conclusions.

After several semistructured sessions, learners use what they have learned about ingredients to prepare recipes of their choice with their preferred taste and texture; these we call *Choice Days*. During Choice Days learners ask new questions and practice using results and conclusions drawn from the experiments done during Semistructured Days to design investigations that help them work together while accomplishing their personal goals. Facilitators play an important role in both Semistructured and Choice Days by helping learners make personal connections to science and scaffolding their scientific practice. For example, facilitators often help learners share their scientific experiences, recognize opportunities to engage scientifically based on their interests, and recognize when what they are doing is scientific. Overall, KSI's design aims to give learners the freedom to embrace scientific practices in their own ways. In understanding how the learning environment facilitated learners' scientizing, we look for the applications in which they choose to participate scientifically. We recognize that these moments and projects may not happen when or where we expect. This is reflected in the design of KSI, as well as in our study design and analysis methods.

METHODS

Our aim is to inform the design of programs and learning environments that will lead more children to scientize. We have done this by first designing KSI and then studying the development of scientific dispositions among participants, what may have been responsible for that development, and from those findings, drawing out implications for design of life-relevant science-learning programs that promote scientizing. In this paper, we focus on the cases of two learners from a multiple-case study of four focal learners in a 9-month implementation of the KSI program. These case studies took place at a local public middle school in the Atlanta metro area during the 2007–2008 school year. We did our best to capture not only interactions and activities within KSI but also relevant experiences in other contexts of learners' lives that affected development of their dispositions, and in which they displayed their scientizing. We analyzed learners' scientific participation in KSI and their reports of scientific participation outside of the program in other settings. KSI was designed and implemented within a larger research agenda: to understand science learning and identity development in the context of a life-relevant science-learning environment.

Data Collection

The KSI program from which we report convened weekly after school as a part of a larger after-school initiative by a local Young Women's Christian Association (YWCA), with the goal of engaging minority teen girls in activities related to science and technology. We had 15–20 consistent participants (seven to nine sixth graders, seven to 10 eighth graders, and one seventh grader), all of whom were African American girls. Four facilitators led the program: KSI researchers (including the authors) and the school program coordinator. Video recordings of each group at every session were collected. In addition, two lead facilitators (including the first author) recorded postobservation fieldnotes after each session to capture the events that stood out as memorable, noteworthy, or instrumental to participants' science learning and engagement.

Our data collection goal was to ensure that we were comprehensive in gathering data that would give us insight into which aspects of the learning environment influenced participants' development of scientific reasoning identities and dispositions. The larger investigation was a multiple case study of four focal learners in KSI (selecting learners with a range of participation styles and interests), Amber, Malaysia, Candyce, and Sharonda (all sixth graders, except Amber, an eighth grader; participants' names have been changed to protect their privacy). Our analysis here focuses on the cases of Candyce and Sharonda.

As a part of our larger study on learners' scientific identity development, we conducted a sequence of three in-depth, semistructured interviews with focal individuals. The interviews were structured similar to Seidman's (1991) phenomenological approach. The approach is aimed at understanding individuals' actions within a particular context and how the meanings they make shape their action. In collecting data for such an analysis, Seidman specifies a three-interview sequence. The first interview is focused on the broader context of one's participation, the second is focused on the day-to-day interactions within a particular context, and the third is focused on one's perspective of themselves and their participation within a context.

We used this method of interviewing because it enabled us to gather data to understand learners' actions as it related to their overarching Discourse participation. However, while Seidman's approach specifies that all three interviews should be conducted within 3 weeks, our interviews were spaced out over the second half of the program to capture learners' change throughout their participation in KSI. Conducting multiple interviews (approximately three) with each participant enabled us to discern consistent patterns, which supported ensuring the reliability of our data (Seidman, 1991). It also allowed us to monitor changes in learners' goals over time and the meaning they were making of their experience in KSI. We also conducted initial and ending interviews with focal participants' science teachers and their parents to triangulate data from observations and interviews with participants. We were able to find out more about the learners' scientific reasoning at home (especially when cooking) and elsewhere through interviews with parents. All interviews were video- or audiotaped and transcribed.

Data Analysis

Given our goal of understanding learners' development of science identities and dispositions, we drew on Gee's (2000) framework for Discourse identity in our analysis to connect learners' external participation (i.e., actions, interactions) to their internal perspectives relating to science (e.g., values, beliefs). Since we were using cooking as a context for promoting children's interest and engagement in science in an out-of-school venue, we also needed to understand *which* Discourses learners were participating in and how their participation in those Discourses influenced their Scientist Discourse.

Identifying Discourses. Our analysis began with using a priori codes for Discourses we expected learners to participate in based on codes developed during previous implementations of KSI (Clegg, 2010). These a priori codes (chefs, kitchen scientists, scientists, product designers) were our initial coding frame for this data set (the larger study of four learners). As we coded against the a priori frame, a new Discourse code emerged, and no evidence was found of others (e.g., product designers). We observed that learners, parents, and science teachers often referred to learners' social motivations in the context of cooking and their engagement in science. Our initial coding of interview data thus resulted in the addition of the Friend Discourse. In addition, we found that the Kitchen Scientist Discourse

TABLE 1
Chef, Scientist, and Friend Discourse Coding Examples

Discourse	Sample Themes Within Each Discourse
Chef	• Create and revise dishes and recipes • Use ingredient and procedural terminology (e.g., "sifting," "browning," "roux", "sauté") • Give and receive detailed critiques on dishes • Carry out complex cooking techniques (e.g., flambéing desserts) • Value the precision used in food preparation (e.g., accurate measurements) • Use kitchen utensils, tools, and equipment (e.g., measuring cups)
Scientist	• Generating new research questions • Designing experiments • Investigate underlying mechanisms • Share experiment procedures and results with others • Critique the methodology and design of other scientists • Value descriptive and quantitative evidence • Value explanations backed by evidence • Use objects, tools, and technology to reduce bias in observations (A priori codes, based on Chinn & Malhotra, 2001)
Friend	• Joking, playing, laughing • Social conversations (e.g., gossip, discussions about personal life) • Use commonly understood slang or shorthand terms • Share common interests and values with people they have personal relationships with • Value engaging in activities with friends • Use objects, tools, and technology to communicate with friends • Collaboratively read or interact with books, magazines, Web sites, etc.

This table shows examples of our coding frameworks for each of the three Discourses we analyzed. The Scientist Discourse codes were developed based on Chinn and Malhotra's (2001) framework for scientific inquiry practices.

was difficult to distinguish from the Scientist Discourse. We therefore collapsed the two codes into Scientist Discourse participation. This is not to say that other Discourses would not be more prevalent in other KSI implementations. Each KSI implementation remains flexible to follow learners' interests and the Discourses in which they participate. The important element for our analytic approach is to evaluate the shifts in the Discourses that learners participate in, and the ways in which these Discourse shifts reveal the progression of their scientific dispositions.

We coded for three resulting Discourses: Chef, Scientist, and Friend. We then developed coding schemes for each of these Discourses based on this previous analysis of emerging codes (see Table 1). Chef Discourse participation included activities and discussions about food, recipes, cooking, and baking. It included looking up new dishes and recipes, using tools and techniques, discussing ingredients, and critiquing dishes. Friend Discourse participation was defined by social conversation, play, and conversations about life and relationships. Participation in this Discourse was characterized by laughter, playfulness, and conversation similar to interactions one might observe in a hallway conversation between middle-school friends. It also included arguments, characterized by emotional tension (e.g., anger, sadness).

Our coding scheme for understanding learners' participation in the Scientist Discourse was based on a framework for scientific inquiry processes developed by Chinn and Malhotra (2001). Specifically, Chinn and Malhotra use a model-as-data method for comparing the way professional scientists conduct experiments to the way that science is typically done in school (which they term simple experiments). In forming a framework for scientific reasoning, they break the processes of designing and implementing science experiments into components including generating research questions, designing experiments, making observations, explaining results, developing theories, and studying others' research. Their framework describes each component in terms of what it looks like to progress from simple to authentic scientific reasoning. We used this framework to identify specific scientific practices learners were engaging in and to recognize when they used them with increasing complexity in a less formal context. In such contexts, inquiry practices may be characterized differently or executed more subtly than in formal settings. For example, in KSI we observed that learners progressed from making opinion observations to making descriptive and quantitative observations (Clegg, 2010). Chinn and Malhotra's (2002) framework classifies this progression as more sophisticated in that learners were making efforts to reduce observer bias in their observations.

Understanding the Progression of Learners' Discourse Participation. Next, we conducted a secondary coding pass through video data of learners' participation in KSI. Relevant days were selected for each focal learner (five to six per learner, spaced throughout their participation in the program) based on interview data. We looked for sessions that contained events learners' emphasized in interviews such as examples of accomplishments, roles they took on, and things they learned. We particularly looked for experiences that learners referred to multiple times (as evidence of the event's meaningfulness to learners). We used software to transcribe active moments in each day (i.e., some nonrelevant conversations were not transcribed). In this coding pass, we used data analysis software, *Transana* (Mavrou, Douglas, & Lewis, 2007), that annotates video episodes with codes and allows grouping episodes by codes. With Transana, we coded all active episodes of transcription (episodes typically ranged from 30 seconds to 3 minutes). During this axial coding process, codes were refined and some new codes were added.

Overarching Patterns of Discourse Participation Shifts. Still working with the larger data set of four focal learners, we categorized codes in each Discourse (for each learner), grouping-related codes in each Discourse together (Saldaña, 2009). We then grouped data chronologically according to the resulting categorization. This grouping enabled us to see learners' scientific progression over time based on Chinn and Malhotra's (2001) framework. It also facilitated the development of higher level summarizing codes at the day and interview level (e.g., looking at the data according to the categories observed for Sharonda, we recognized Day 7 as a day that she began to take "more active participation," and we coded this day as such).

Connections Between Discourses. We then created a metamatrix (Miles & Huberman, 1994) consisting of a chronological layout of all four cases, organized by learner (i.e., each of the four focal learners), Discourses (i.e., scientist, chef, friend), and aspects of each Discourse (e.g., ways of acting, interacting, feeling, believing, valuing, speaking and writing) as defined by Gee's (2001) Discourse analysis framework. These data were additionally partitioned by their Discourse participation at home, in KSI, and in science

TABLE 2
Across Case Metamatrix Frame

	Amber			Malaysia			Sharonda			Candyce		
Changes in Scientific	H	K	S	H	K	S	H	K	S	H	K	S
Speaking or writing												
Acting and interacting												
Using face or body												
Feeling, believing, valuing												
Using objects, tools, and technology												
Influence of other Discourses:												
Chef												
Friend												

This table shows the framing of the metamatrix produced that depicted the major Discourse themes observed for each of the four focal learners across home (H), KSI (K), and school (S).

class (as the data we collected were primarily in reference to these three contexts). The framing of this metamatrix is shown in Table 2.

This metamatrix helped us to identify each learner's (i) use of scientific practices (ii) increases in quality and quantity of those practices, and (iii) influences on that development, which our conception of scientific dispositions and their development suggests that the analysis needed to identify. It also helped us to trace learners' goals with respect to scientific reasoning (Chinn & Malhotra, 2001) and KSI participation, as well as the actions, and interactions that were motivated by those goals to understand what led or did not lead to scientific reasoning.

Mapping Participation and Value Shifts to Identify Dispositions. To understand learners' development of scientific disposition, we analyzed the development of learners' Scientist Discourse participation and the events that seemed to trigger that development. We looked for increases in the quality of learners' scientific reasoning and their use of scientific practice in other Discourses (Bereiter, 1995), particularly that which was self-initiated. Our examination of learners' evolving patterns of engagement in scientific reasoning across Discourses revealed how it was becoming a part of who they are, particularly, with respect to their scientific confidence, interests, and ability to create new opportunities for reasoning scientifically.

Next, we created within-case diagrams (Lee & Lings, 2008) that were condensed representations of the constructs for each learner (Figure 1). In these diagrams, we highlighted overarching value shifts (from the metamatrices) that seemed to characterize learners' participation shifts in and across Discourses. We recognized these value, ideal, and perspective shifts as *dispositions* that characterized and seemed to influence learners' consistent participation.

Progression of Learners' Dispositions Across Cases. Finally, we looked across representations to identify common themes in the progression of learners' disposition shifts. Although each learner's participation progressed differently, we found there were trends across cases in the progressions of learners' scientific dispositions—their use of scientific inquiry practices for achieving cooking goals, participation shifts as they took on more

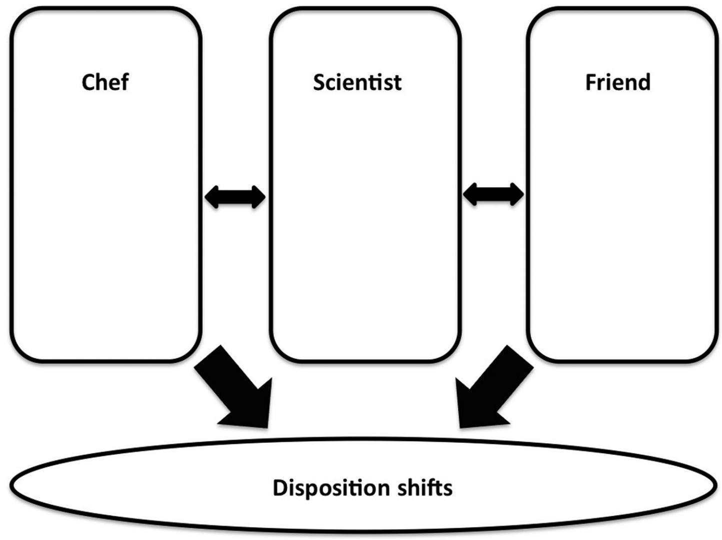

Figure 1. Within-case diagram framing.

scientific roles, and value shifts that influenced their use of scientific practice in other settings. Tracing these progression themes back to the metamatrices, we were able to identify general themes that emerged in terms of the activities and interactions in learners' lives that promoted and prohibited their scientific participation and dispositions—e.g., influence of activity sequencing, scientific or social experiences unique to the individual or small group, and help from peers and facilitators on learners' scientific participation and values.

FINDINGS

For brevity, we only report two cases in this article. However, looking across all four cases, we found that each focal participant came to more fluidly and consistently engage in scientizing as they participated in KSI (Clegg, 2010). Here we present the detailed cases of Sharonda and Candyce, two sixth graders that embody the themes observed across cases. We selected these two cases because they comprise the richest data sets and were the most illustrative of Discourse participation and shifts in scientific dispositions (though shifts were observed across all four cases). We first present learners' day-to-day experiences in KSI to understand how those experiences promoted scientific practice. We then present how their scientizing began in KSI and continued in their homes and science classes. This allows us to understand how learners' day-to-day experiences promoted more epistemic or systematic development of scientific dispositions. Incorporated in these descriptions are aspects of the learning environment that influenced learners' scientific participation and more epistemic development of scientific dispositions. We specifically draw upon these characteristics in the discussion.

Sharonda: Day-to-Day Experiences

When Sharonda joined KSI, she was particularly quiet during whole-group conversations yet playful with her friends in their small group. Although Sharonda remained quiet in whole-group conversations, she began to take on more scientific roles in her small groups over time as she discovered the importance of measurement. Her group made an early mistake while measuring that they learned from. Recovering from their mistakes helped Sharonda develop measuring skills and take on a leadership role in her small group. Her increased scientific participation and her increased recognition of the need for precision helped her to develop scientific disposition. We trace this development, beginning the case description on Day 6.

Day 6: Horrible Cooking Mistake

Session Overview. Day 6 of KSI was a Semistructured Day on which each small group was making the same chocolate chip cookie recipe while varying the leaveners used to learn more about baking soda and baking powder. One group used baking powder, another group used baking soda, and a third group used baking soda and baking powder in their cookie recipe. Sharonda worked with two other sixth graders: Esha and Treeva. Their group was charged with making the baking soda and cream of tartar variation of the cookie experiment, and Christina was their facilitator.

Session Specifics. While Sharonda asked Ayanna, a YWCA counselor, a question about how to measure, Treeva measured the leaveners for their cookies. She used a measuring *cup* for the baking soda measurement instead of a *teaspoon*. The group confused measuring spoons with measuring cups again when they measured the sugar for their recipe. Christina was able to catch them and correct their mistake by clarifying the difference between a teaspoon and a cup. Christina also corrected their understanding of fractional measurements (e.g., $\frac{1}{2}$ and $\frac{1}{4}$ cups together equal $\frac{3}{4}$ cups). In the whole-group conversation, Sharonda's group's mistake became public, as everyone tasted their variation. Sharonda remained quiet in the background, whereas Esha and Treeva tried to warn others about their baking soda filled cookies. When the others tasted their cookies, they were shocked by the "horrible," salty cookies.

Day 7: Taking a More Active Role

Session Overview. During the next session of KSI, Sharonda continued to work with Treeva and Esha, as well as facilitator Christina. The activity that day involved measuring leaveners for a science experiment to see how leaveners react to produce air.

Session Specifics. At the beginning of the session, Sharonda measured ingredients while Treeva and Esha argued with one another. Then Sharonda walked away and spent some time standing at the door and talking to a boy from school. Christina helped Sharonda become a more active participant in the group when she returned. She gave her a camera and instructed Sharonda to "take pictures of your cups while you guys are adding stuff." Sharonda began to take on the role of photographer for the group. First, she took pictures of their experiment variations (leaveners mixed with water and other liquids) and of the group members posing with the variations. She began taking more initiative as photographer by organizing group members and lining up experiment variations to create a picture.

Christina then encouraged Sharonda to take ownership of a variation herself as Treeva and Esha had been doing by measuring and adding the active ingredients to the cup. While Sharonda mixed the leavener and water, Treeva took a picture of Sharonda and her leavener. Sharonda then went to the observation chart to record what happened. When she returned, she resumed her role as photographer by taking pictures of the leaveners before, during, and after each reaction. She also continued to take ownership of more variations and of recording additional observations.

Day 9: Becoming the Group Measurer

Session Overview. Day 9 was the first Choice Day in KSI when learners could choose a new recipe to make. Still working with Esha and Treeva, Sharonda's group chose to make cupcakes.

Session Specifics. First, Sharonda took responsibility for going across the room to fetch and measure buttermilk for the group. Christina pointed to the cup and spoon she would need for the measurement, and Sharonda carried out the measurement on her own. Sharonda began to take ownership of the buttermilk when she returned; she made sure to add it to the batter herself. The group later did an impromptu experiment resulting from their curiosity about buttermilk. Sharonda initiated her role as group measurer when she volunteered to measure more buttermilk for the experiment variation.

The group did a second variation of the impromptu experiment, replacing buttermilk with lemon juice. This time, Sharonda asserted herself in the experiment by adding baking soda to the variation. She continued to monitor, make observations, and report those observations of the mixture to others as they resumed cooking. She also presented the contents of their experiment variations to nongroup members who asked about it while describing the reactions previously observed.

Day 11: Taking Initiative in Her Small Group

Session Overview. Sharonda continued to work with Esha, Treeva, and Rachel with Christina as their primary facilitator, this time taking on more leadership roles within the group. The activity that day involved making biscuits using what they learned about leaveners to alter the recipe. They also began to explore thickeners by making gravy from a packet.

Session Specifics. Sharonda took leadership in preparing their dishes even though she did not lead her group in making recipe decisions. Sharonda called out the measurements and ingredients they needed, delegated tasks, and measured ingredients. More serious participation was evident as she yelled at her teammates several times for playing as they cooked.

While Sharonda prepared the gravy with Christina, Christina encouraged Sharonda to think about a question posed earlier to the whole group: What makes gravy thick? They looked at the ingredients list on their gravy packet to begin exploring the question. They began to search for the ingredients on the Internet together when they were unfamiliar with some of them. Christina helped Sharonda interpret the Internet definitions, and together they hypothesized about whether or not each ingredient might thicken the gravy based on the information they had found. Although some of Sharonda's comments indicated she had trouble understanding the concepts of thickening and leavening, Sharonda remained engaged throughout the investigation. At times when Christina was called away, Sharonda continued to search for ingredients on her own and later asked Christina for help to interpret her search results. In later interviews, she described the investigation as fun, useful, and something she could even take home and share with her mom.

How Sharonda Began to Scientize In and Out of KSI

Sharonda's Scientizing Began in KSI. Sharonda's mistakes as a chef helped her begin to value precision in her recipe preparation. Recognizing the need for precision later impacted her Scientist Discourse participation. Sharonda began to take on more active roles in her small-group activities as she learned to measure; this allowed her to observe the scientific reactions in their dishes and experiments while engaging in side investigations to answer new questions. As she began to increasingly value precision in her cooking, she also started to think about the effects of adding different types and amounts of ingredients to her dishes.

Although Sharonda progressed in thinking and acting scientifically, our data showed that she did not gain an accurate understanding of the scientific concepts we discussed in KSI. However, one should not discount what Sharonda learned about being a scientist. When asked questions about the science that she learned and the progress she made in KSI, Sharonda reported learning to measure and could express what she had learned.

Sharonda also developed new and closer friendships with her peers while participating in KSI. These friendships promoted, yet occasionally hindered, Sharonda's Scientist Discourse participation. Sharonda reported that developing friendships with her peers in KSI made science more fun. However, conflicts arising in these friendships sometimes caused Sharonda to be shy or distracted from scientific participation in KSI. Relationships with adults in KSI also influenced her scientific participation. Sharonda engaged in side conversations of diverse topics with KSI facilitators while they cooked together, such as childhood experiences or Asian and American cultures. In addition, Sharonda's science teacher was the faculty coordinator for the larger TGI-Tech program that housed KSI. Her science teacher felt that the increased exposure helped her students in KSI to feel more comfortable and to better understand her expectations of her students in science class. These relationships may have helped Sharonda to feel more comfortable asking questions and taking on new roles in KSI.

Scientizing Continued at Home. Sharonda's mom let her help with cooking at home after Sharonda had more cooking experiences in KSI. Her mom reported that Sharonda would give short explanations when they encountered ingredients and phenomena that she learned about in KSI. Sharonda also sought opportunities to cook at home. She took KSI recipes home with her often so that she could remake them, correcting their previous mistakes. She and her mom then began to expand upon KSI recipes by creating their own unique recipes from them. With additional cooking opportunities, Sharonda may have had more chances to use and extend her scientific measuring skills and to explore more of the underlying scientific phenomena in the foods that she cooked. Sharonda's mom reported that her daughter began to think of the components of food and that she was able to explain the steps of how foods change from one state (e.g., batter) to the next (e.g., cake), while observing those changes as she cooked. She also reported that these connections outside of school, specifically in the context of cooking, later helped Sharonda to become more conscious of science in her every-day surroundings (e.g., thinking about how science relates to animal reproduction).

Scientizing Continued in Science Class. We conducted two interviews with Sharonda's science teacher, one at the beginning of the second half of the program and a second after the program ended. During the initial interview, Sharonda's teacher reported that, similar to our observations in KSI, Sharonda was having difficulty in science class with comprehension, following procedures, and mathematics. In ending interviews, her science teacher reported that she was able to make connections from KSI to the science curriculum. Sharonda's teacher believed that she identified with measurement conversions that they did in science class because of her familiarity with measurement concepts in KSI. It was also possible that Sharonda was able to talk about density and thickness from her experiences in KSI.

Developing new friends and taking on new roles in KSI may have also had a significant impact on Sharonda's participation in science class. Sharonda's teacher reported that her difficulty understanding had impacted her participation in science class. Sharonda's silence, looking away, only following directions, and not volunteering during small or whole-group activities was initially described as a "don't-call-on-me presence."

Sharonda's science teacher observed that she became more socially confident in KSI. Her teacher reported that since her participation in KSI, Sharonda had also become more confident and careful about her work in science class while working in teams. It was clear that Sharonda was taking more initiative in her groups rather than merely waiting for directions as she had done before. For example, her teacher noticed that Sharonda became more careful in her work as well as excited about atmospheric projects when they measured humidity, amounts of rain, and heat. She reported that Sharonda was able to quickly grasp measurement conversions most likely due to her familiarity with measurement in KSI. As a result of those measurement experiences in KSI, her teacher also reported that Sharonda helped peers in the class with measuring liquids into beakers and that students were approaching Sharonda for help:

> Science Teacher: She wants to help kids in her group with stuff and say, "Let me help you this time." And not always being the one saying "I need help." I mean she still asks for help, but if there are other people in her group that she can help then she will, you know, turn around and help them. And I've seen that—I've noticed even some students actually going to her for help. So, that's a big change.

By the concluding interviews, Sharonda's teacher had also noticed changes in Sharonda's individual participation due to the relationship that they had established in TGI-Tech and KSI. She reported that Sharonda had an increased comfort with seeking help. Sharonda would come to her before or after class to finish work, help with grading papers, or just to talk. By her last interview, Sharonda's teacher had also reported that Sharonda's participation began to change. Sharonda was participating more in class, asking questions, raising her hand, finishing her work, and helping the teacher with grading.

How Sharonda's Scientizing Progressed. Recall that we define dispositions in terms of values or ideas that a learner takes on that help them to participate more consistently in a discipline. Sharonda's disposition development is therefore characterized in terms of values she developed that offered the potential to promote more frequent and voluntary scientific participation. Specifically, two disposition changes emerged in Sharonda's case. She developed values, first of precise measurement and, second, of taking risks and making mistakes.

Sharonda understood that imprecise measurements and incorrect amounts of ingredients would cause negative cooking results, although she did not always grasp the scientific concepts or accurately interpret the results of experiments. From her experiences, she began to see the effects of adding the wrong amounts of eggs, baking soda, baking powder, yeast, arrowroot, or cornstarch. As she had those experiences and took on the role of measurer, Sharonda began to master the skill of measuring precisely. By developing this value and skill, Sharonda was able to help others in her science class and give explanations to her mom about the effects of ingredients.

The second disposition shift that we observed in Sharonda's case was that she began to value taking risks and making mistakes. Sharonda initially reported that although "good scientists" took risks and made mistakes, she was afraid. She stated that she was afraid to try new things, like touching leaves, interacting with dogs, and even tasting their initial KSI dishes. However, Sharonda was able to develop a mastery of precise measurement in KSI that helped her recover from her group's earlier cooking mistakes to make successful dishes. By the end of the study, Sharonda was taking the risk of trying to make new dishes in KSI and at home.

We suspect that Sharonda was not only afraid to try new things with cooking, but she may have also been afraid to participate in new ways. Her cooking and science (i.e., measuring) accomplishments may have helped her to take the risk of more leadership roles in not only her KSI small groups but also in her science class small groups and even with her science teacher (e.g., asking questions when she did not understand). Thus, developing such a value may have shifted Sharonda's participation across the Chef, Friend, and Scientist Discourses.

Our data suggest that Sharonda herself recognized that she had changed and saw these changes as scientific. Throughout interviews, she emphasized proper measurement, taking risks, and making mistakes as important practices for scientists. In practice, her risk taking ranged from trying to carry out cooking experiments to trying science experiments to taking initiative to talk to her teacher. In addition, Sharonda included the study of food as a characterization of scientists' work, and she saw KSI facilitators as exemplary scientists. Sharonda described her own participation in these endeavors as scientific. Specifically, she described the development of measurement skills as progress she made as a scientist. Sometimes, Sharonda distinguished scientists from kitchen scientists (e.g., in her description of the tools used by the two groups and in her characterization of her intended participation in the two groups), connecting her own participation as engagement in kitchen science rather than science itself.

Candyce: Day-to-Day Experiences

Recall Candyce from the introductory excerpt: a sixth-grade learner who showed interest in science and cooking in KSI but initially did not see herself as a "sciency" type of person. Candyce began participating in KSI during the second semester of the program (Day 11) as the group began investigating thickeners. We selected Candyce as a focal learner because of her participation style in KSI. She was often vocal in whole-group conversations, but she was quite reserved during small-group interactions. In KSI, Candyce began to connect science to her everyday life. Through making descriptive observations, Candyce began using experiment results to form specific goals for her foods. She then needed to use those results to make decisions about how to achieve her cooking goals. In doing this, Candyce was participating in scientific inquiry and building explanations that were relevant to her cooking. We trace Candyce's progress through KSI by detailing changes in her scientific, social, and cooking participation in KSI.

Day 12: Connecting Science and Cooking

Session Overview. Candyce began participating in KSI halfway through the 9-month KSI implementation, so Day 12 was her second day of the program. During this session, Candyce engaged in a whole-group conversation where she began to make descriptive observations about food. She also worked with Amber, Mikayla, and Precious making a white rice flour variation of a pudding experiment the whole group was conducting (making pudding with different thickeners).

Session Specifics. First, during the whole-group discussion, Candyce worked with a subset of the whole group to make observations about different store-bought puddings and custards. Her group initially made observations based on their opinions of the foods they tasted (e.g., "it's nasty!"). Christina, the facilitator, encouraged them to describe the characteristics of the food instead. Candyce then began making descriptive observations, (e.g., "It's sweet and it's mushy").[1] Their group also created a test for thickness after receiving encouragement from Christina. They measured how long the different puddings stayed on the spoon when turned over, ranking the puddings afterward by how long they stayed on the spoon. Candyce continued to suggest new puddings to compare using the spoon test and later volunteered with another group member to present their results to the whole group.

Later, when the whole group decided what each group would vary in the pudding experiment (types of thickeners), the facilitators prompted learners to think about what to keep constant in the experiment. Candyce immediately volunteered when Tammy mentioned stirring. She then talked about how her mom made pudding at home, thereby giving the group her mom's advice for how to stir pudding, (i.e., "stir from the bottom and go up"). When Christina asked Candyce to stand up and show the group how to stir, Candyce became the teacher and gave her own advice as opposed to her mom's, specifying the motions for stirring.

Candyce also used her previous experiences making pudding at home to predict the results of their pudding experiment. She referenced these experiences when predicting several times that milk would thicken the pudding. Making descriptive observations of their pudding experiment results, she compared her pudding at home to their pudding that day while noting that their pudding in KSI was grittier than the pudding from home.

Day 16: Application of Experiment Results

Session Overview. On Day 16, Candyce engaged in a Choice Day investigation, making fruit tarts with another sixth-grade KSI participant, Malaysia, and facilitator Janet.

Session Specifics. Candyce was encouraged to ask questions during the whole-group discussion when the facilitator, Janet, noticed that Christina used a word (molecules) during the group discussion that they might not have been familiar with. Janet asked the group if they knew what the word "molecule" meant. When no one spoke, she told them to "Ask what a molecule is if you don't know." Candyce and others asked what the term meant. Janet responded, "Molecules are made up of atoms." Still not sure of the meaning, Candyce continued to ask a series of questions until she was satisfied with her understanding of the term.

The group then moved onto their Choice Day recipes in their small groups. After Candyce and Malaysia decided to make fruit tarts, Janet led them in completing a paper-based goals chart, describing their goals for the taste, texture, look, mouth feel, and smell of their dish. Janet helped them look back at the pudding experiment results (using different thickeners) from Day 12 to select an appropriate thickener. They selected the thickener(s) together that best matched the goals they had for their fruit tart filling. They wanted their custard to be soft, creamy, moist, and smooth with a sweet and "fruitiliscious" taste. They therefore decided to use arrowroot and white rice flour because each of those variations of pudding produced a subset of the results they desired. Candyce carefully measured ingredients and

[1]Chinn and Malhotra (2001, 2002) characterize the shift from making opinion observations to making efforts to reduce observer bias in observations (in this case with descriptive and quantitative observations) as a progression in the complexity of learners' scientific inquiry practices.

monitored the results of their filling as it cooked. They were very pleased with their resulting fruit tart and especially excited to take mini tarts home to their families.

Day 17: Undesirable Result Leads to Curiosity

Session Overview. Each group was asked to remake their dish from the previous week so that they could present it to the whole group on Day 17. Continuing to work with Malaysia and Janet, Candyce's group experienced unexpected results as they remade their fruit tart that sparked Candyce's curiosity.

Session Specifics. The custard filling from Candyce's group this week became "rubbery" despite the group remaking the tart with the same thickeners they used the previous week. This undesired result made Candyce wonder what caused the difference. As Janet used the computer to help this team write a story about their fruit tarts to share with the whole group, they discussed the differences in their custards and possible causes for those differences. Candyce suggested, "I think it's because we let it stay on there longer, and we might've added more arrowroot." Janet didn't think so but did not suggest any alternate explanations. Candyce continued to wonder about what caused the difference, "I wonder what happened. Maybe it was slightly more arrowroot." This time, Janet disagreed and said that she knew that they added the correct amount of arrowroot for the recipe. During the ending whole-group discussion, Candyce volunteered their group to present first. Their group was asked how they knew arrowroot would produce certain results, and Candyce emphasized that they used the results from the pudding experiment (on Day 12) to decide which thickener to use. Candyce and Malaysia read their story about the first time they made the tarts, and then Malaysia described their rubbery custard experience with extra emphasis on surprising or meaningful aspects added by Candyce.

Day 20: New Question Leads to a New Experiment

Session Specifics. Learners once again chose a recipe to prepare, this time involving leaveners, thickeners, or a combination of the two. Candyce chose to make a chocolate version of a yellow cake recipe that they made previously with a cream filling. Their group, including Candyce, Treeva, and Rachel, working with facilitator Tammy, had to use what they knew about thickeners to determine which thickener and how much of it was appropriate for the cream center.

Session Specifics. While they were preparing their cake, Candyce noticed that the buttermilk they were using was "creamier" and "thicker" than milk. She asked about the difference between buttermilk and whole milk. Tammy began to explain the difference but stopped and began to reenact part of an experiment they had done previously when they were investigating leaveners.

Tammy mixed baking soda with whole milk. As Tammy measured the milk, she asked the group to make predictions. Rachel predicted that the mixture would not bubble up. After adding the regular milk to the baking soda, they saw that nothing happened with the mixture. Next, they mixed baking soda with buttermilk. Tammy again asked the group to make predictions about what would happen. Rachel thought that the mixture would bubble, and this time was about to explain why when Candyce completed her sentence by stating the buttermilk was more "concentrated." As Tammy poured the buttermilk into the glass, everyone was surprised to see that nothing happened. When Tammy held the buttermilk glass in the air, the mixture began to bubble. Amazed at the size and appearance of the bubbles, all the girls leaned over the table to watch what was happening, clearly wondering why. Tammy told them that air was produced because buttermilk is an acid and baking soda is a base. The group continued making the cake as Candyce periodically noticed changes in the smell and look of the buttermilk glass and made descriptive observations.

Later, when they started on the batter for the cream center of their cake, Candyce again used the results of the Day 12 experiment to suggest which thickener to use. Tammy brought each of the thickeners to the table and asked them which one they thought they should use. Candyce immediately knew she did not want tapioca and reminded the group that the tapioca pudding on Day 12 was lumpy and slimy. Tammy reminded Candyce and Rachel of the thickeners that they used in their sweet and sour chicken from the week before, where they used arrowroot and white rice flour to thicken the sauce. They unanimously agreed when Tammy asked whether they wanted to use the same combination for the cream filling in their cake. However, when she asked them what texture they wanted the filling to have, Candyce said they "want it really creamy, so we should just use arrowroot because that one came out creamier."

How Candyce Began to Scientize In and Out of KSI

Scientizing Began in KSI. Candyce was immediately able to connect her experiences in KSI to experiences at her home. She also immediately began making observations, making them more scientific in nature (i.e., descriptive, comparative, and quantitative). She found that those observations helped her to create more specific goals for her foods and to draw evidence-based conclusions about how to achieve the goals she had for her foods. She was also encouraged to ask questions in KSI, and she began to enthusiastically wonder why and ask questions when she obtained unexpected cooking results. In addition, she began to ask questions to learn more about ingredients. As she had experiences in KSI, Candyce began to develop scientific reasoning skills (i.e., asking questions, making descriptive and quantitative observations, sharing and applying experiment results) and understanding about how starches work in dishes. She also began to value the scientific explanations the girls constructed during their cooking investigations as useful for making explanations in her daily life:

> Candyce: I think [experiments in KSI are] useful because sooner or later we're gonna have to use it, so I think it'll be useful . . . in our adult life, as far as our daily life, because when we get older and have kids or something we can tell our kids like, not just to do it, like why it makes it like that.

She also felt that she was better able to understand these explanations in KSI because of the facilitators' willingness to explain:

> Candyce: Like you guys um, you explain things, like I said before, you explain it and help us with things that that we might need help with, instead of our other teachers, they just tell us . . . once and then just walk off without explaining it and really breaking it down so you can explain.

Scientizing Continued at Home. As Candyce engaged scientifically in KSI, she began to recognize the utility of scientific explanations at home and engage scientifically with her mom and brothers. Candyce initially wanted more explanations of how ingredients work in foods when cooking at home. She used the results of KSI experiments and investigations to make recommendations to her family. As she connected her pudding experiments at home and in KSI, she reflected on how she and her mother could have made their pudding better:

> Candyce: Um, well now when me and my mom cook together, I can like tell her like, the different thickeners she could use in this certain recipe if she wanted to. Like once me and my mom made homemade pudding—this was before KSI—and I was thinking about that experience when we made pudding because my mom wanted to make it over the oven, and I thought, 'Oh my gosh, if I was in [KSI] back then I could've told my mom we could use a type of thickener like arrowroot or something.

Candyce had begun connecting cooking and science in family discussions outside of the home by the end of the program. Her mom reported that Candyce would reference her KSI experiences at the store when she described ingredients and their purposes to her.

Scientizing Continued in Science Class. Candyce could not initially make the connection from science class to her life. As a result, she was finding science in school to be boring. When initially asked what she liked most about her science class, she replied, "Nothing! I hate my class." Candyce was frustrated with the lack of utility and with the test-based emphasis of science class. She found the experiments boring and that they "did not catch her attention." Candyce's teacher was also initially frustrated with Candyce's lack of participation in her class. She saw "no real active participation from Candyce," stating that she "did not put forth much effort to get to the right answers," and often needed help.

When Candyce began the KSI program, her science teacher was also frustrated with her behavior and attitude in science class. She observed that Candyce was in a class with disruptive students and that she began to behave similarly. Her teacher suggested that she switch to a different class to address Candyce's behavior issues and to help raise her grade in science. Candyce was therefore switched to the teacher's "sunshine class," a class with students more focused on their schoolwork, just prior to joining KSI. Although there were still some disruptive students, the class tended to engage in "friendly competition" to do well, and they received more praise from the teacher than did other classes. Both her science teacher and mother reported that she was doing better in this class; she was volunteering to speak, giving correct answers, and asking the teacher questions outside of class. In KSI, Candyce developed a "craving for knowledge"; she felt she "had to know." She stated in the second set of interviews, "I like finding things out, um because I'm like the type of person who will want to know something and who loves getting information. So I'm good at that." As Candyce participated more in KSI, she began taking this craving into her science class:

> Tammy: . . . What progress have you made as an investigator since being in KSI? Candyce: Okay, I like to, well, now like, in my other everyday life, like school. I like to sit in class more and think about why it has to be like that. Like in science, my teacher was telling us about the stone age of things. And I was like why did it have to be like that and who may have thought of doing that or something.

This "craving for knowledge" was important for Candyce with respect to her general interest in science. Without it, she felt that she "probably wouldn't like science at all." By the end of the program, Candyce was not only connecting KSI topics to her life (e.g., thinking about types of heat in cooking), but she was also connecting science class topics to her life. For example, she connected the concept of black holes to her life:

> Candyce: It's really interesting because I think about like how cool it would be to see a black hole, but then it makes me like worry about it. Because if you fall into a black hole you're not getting back out. And um, I think it's real interesting how stars can collapse into itself and make a black hole and stuff.

However, Candyce still found the science tests to be difficult in that there was a lot to remember.

How Candyce's Scientizing Progressed. Candyce's scientizing progressed along three paths in KSI. First, she developed an ability to understand in KSI (whether perceived or actual), and she attributed this to facilitators' patience and explanations. In addition, we observed that her examinations of the effects of thickeners and side investigations where she observed results herself had also helped her to understand the concepts in KSI. Candyce also developed a "craving for knowledge" as she participated in KSI. When she began participating in KSI, she did not see the practicality of course material from her science class and therefore found it to be boring. In KSI, our data suggest she was able to relate science to her life in a way that was useful to her. A deeper interest in science arose as Candyce continued to participate in KSI, reporting that she had developed a "craving for knowledge" in her science class.

As Candyce developed a "craving for knowledge" and found what she was learning in KSI was applicable outside of the classroom, she began to make connections to science in other contexts. She connected the concepts of thickening and types of heat from KSI to her science class. She used her knowledge of thickeners at home and at the store. She even connected the measurements they took of their results in KSI to learning to measure in mathematics class.

Interview data suggest that Candyce's perception of her scientific participation changed over the course of her participation in KSI. In the first two interviews, Candyce described her participation in KSI as investigation. She characterized investigation as problem solving and finding out new things. In fact, she described her craving for knowledge as progress she made as an investigator. However, she characterized science more broadly to include making the world a better place by creating inventions and finding cures for diseases. By the end of KSI, the fields of investigation and science were intertwined for Candyce. She reported that investigation was the most important aspect of science.

Candyce's career aspirations throughout the study followed a parallel trajectory. Candyce was considering becoming a computer technician, Web designer, and chef in initial interviews. In the second set of interviews, Candyce described (in this article's opening excerpt) her career considerations in terms of the aspects of investigation she emphasized—solving problems and discovering new things in the context of cooking. By ending interviews, her intertwining of science and investigation was portrayed through her consideration of becoming an astronomer. Candyce's interviews suggested that she saw herself first as an investigator and as she merged these two fields, she may have begun to consider herself as a scientist.

DISCUSSION

How Day-to-Day Experiences Promoted Scientific Dispositions

Recall that the goal of the analysis presented in this paper is to understand how we can help youth recognize the value of science in their lives, increase their motivation to learn science, and begin to take initiative to see the world in scientific ways. Analysis of learners' day-to-day experiences enabled us to ascertain (1) what motivated learners' scientizing and (2) how it progressed. Understanding the influence of the learning environment on learners' scientific participation then allowed us to identify (3) the aspects of the learning environment that promoted the progression of learners' scientizing. The cases of Candyce and Sharonda are complimentary in that they allow us to see how different paths, values, and scientific practices can lead to development of scientific dispositions and Discourse participation. Their cases show the commonalities observed in all four cases with respect to how learners progressed to scientizing (Clegg, 2010).

Motivation for Scientizing: Influences of KSI. The similarities across the two case studies that have been presented provide a broad view of the ways KSI helped participants become interested in and begin to scientize. Participants' experiences in KSI and interactions with others helped them to make tasty dishes that they were proud of creating. Over time, participants began to value scientific practice and others who were interested in science. As they used science to achieve their cooking goals, they saw the relevance of science for achieving their goals. They were able to connect science to their real-world experiences and their interests with mastery of scientific practices. In doing so, learners were then *disposed* to use science, i.e., to think about science in new contexts (at home and in science class), which, in turn, led to increased scientific participation and increased participation as scientists. In essence, KSI helped participants see the relevance of science for cooking, which then helped them come to value its relevance in other parts of their lives.

Furthermore, KSI participants had a chance to interact with peers they had not spent time with before, and some participants made new friends. KSI participants also had opportunities to take on leadership roles with their new friends in KSI, leading them to feel confident in taking on such roles. This combination then influenced learners to participate more scientifically in the broad variety of contexts in which science was relevant—in KSI, at home, and in science class. As they began using science in more of the contexts of their lives, scientific participation then became a more stable aspect of their engagement in these contexts. Participating in KSI both as chefs and as friends was important to the participants' development of scientific dispositions.

How Scientizing Progressed. Once learners' scientizing was initiated, we found that it progressed in three phases. First, the scientizing process was initiated as learners *used science to accomplish personally meaningful goals*. These personally meaningful goals, though different for each learner, were all in the context of making tasty dishes. As learners began to use science to accomplish their goals, their *participation shifted*. As they began to take on more scientific roles in KSI, both learners' engagement involved the development of scientific inquiry skills. Sharonda became a skilled measurer, and Candyce became knowledgeable about thickener effects. Both then began to connect what they had learned during scientific experimentation to their goals in making new dishes. As learners had more scientific experiences and as they continued to participate scientifically, their *values shifted* in ways that fostered learners' personal connections to science. These personal connections (e.g., valuing risks and mistakes, valuing curiosity) offered the potential for new motivations and opportunities for learners' increased participation in science.

The patterns of interaction that we see our focal learners trace, from their initial motivations to their progressions to scientize, are reflected in Nasir's (2002) identity, goals, and learning framework, which serve as a basis for our approach in designing life-relevant learning programs. When viewed through the lens of Nasir's (2002) framework, learners' personal *goals* spark their motivation to scientize; their evolving practices map to their *learning*; and these practices affect emerging personal values that reflect their *identity*. Our findings extend Nasir's framework by overlaying a lens of disposition as the mechanism for informing our understanding of identity development.

Specifically, we found that learners' motivation to scientize started with their personal *goals* related to cooking and social interactions that, in turn, led them to develop more scientific goals, which then motivated learners' increased scientific participation. We suspect that connecting their personal goals to science may have impacted learners' willingness to draw upon science in new contexts or applications, which then may have prompted participants to learn new scientific practices. As learners developed scientific skills and practices (the *learning* aspect of Nasir's framework), the practices they developed (e.g., precision, curiosity, investigation) became connected to their personal values, which influenced their *identity*, as observed through our analytic lens of scientific dispositions. As learners saw the benefit of these practices and became interested in them, the scientific practices became connected to their personal values, potentially shaping the development of their dispositions. From our analysis regarding the evolution of their dispositions, we glean deeper insight into identity development.

Implications: Understanding the Development of Scientific Dispositions

Our work sits between formal (school) and informal (out-of-school) learning contexts and characterizes scientific Discourse participation and dispositions by a combination of learners' procedural and conceptual understanding, interests, social interactions, and personal connections. In this space, we present a characterization of the development of scientific dispositions that moves in small increments, varies from person to person, and often cannot be recognized until later. We believe this in-between perspective offers a powerful characterization of scientific dispositions because it considers scientific practices in the languages of out-of-school contexts and captures development often missed in formal evaluations. Scientific dispositions from this perspective actively consider learners' personal connections and scientific practice to promote deep sustained interest and engagement in science.

Our findings are consistent with and advance Gee's (2001) framework of "Discourse" identity. Our analysis yielded themes of learners' participation across Discourses in each case. These themes connected directly to the scientizing shifts we found for each learner. Tables 3 and 4 show that each of these Discourse themes connected directly to values and ideas about science that impacted each learners' consistent engagement in science (i.e., the development of their scientific dispositions). For example, as Candyce began to ask new questions, she developed a craving for knowledge that helped her to become more engaged in science class.

We found that each learners' Scientist Discourse participation started with their own explicit connections between their personal interests and science. This Discourse participation progressed to include a development of procedural and conceptual understanding and social interactions around science. Learners' scientific dispositions then took shape through the development of scientific values, or personal connections to science that encouraged active engagement in other contexts (see Table 5).

Our analysis of learners' development of scientific dispositions enables us to expound upon the impact of the progression of learners' scientizing with respect to the building blocks of disposition development. Helping learners develop interest in science through applying scientific practices to other Discourses they are interested in can serve to spark *curiosity* about other scientific endeavors. Social interactions with others who share learners' interests can then facilitate learners' increased participation in other *communities* (family and classroom in these cases). Procedural and conceptual understanding can then help learners to develop *competence* to engage successfully in scientific endeavors, thereby helping learners to accomplish their goals. Finally, personal connections to science can help learners to personally *see the value* of science in their lives and make their own individual *commitments* to consistently engage in science across the Discourses and settings of their lives.

TABLE 3
Mapping Sharonda's Discourse and Disposition Development

Discourse Theme	Connection Between Discourse and Disposition	Disposition
Fixing cooking mistakes	As Sharonda experienced the importance of measuring for creating tasty dishes, she began to value measuring accurately.	Value of precision
More active role	As Sharonda began to take on new roles, she began to take the risks of trying new things and even making mistakes. A key may have been learning to recover from her mistakes.	Value of taking risks and making mistakes

TABLE 4
Mapping Candyce's Discourse and Disposition Development

Discourse Theme	Connection Between Discourse and Disposition	Disposition
Descriptive observations	Candyce reported that she was able to better understand science in KSI. But we observed that as she directly experienced reactions and results in KSI, she asked for explanations about the underlying science. In such contexts, she engaged in conversations until she was satisfied she understood.	Perceived ability to understand
Asking new questions	As Candyce began to ask new questions and consider the connection of science to her life, she developed a craving for knowledge, which helped her to ask new questions in other contexts.	Craving for knowledge
Connecting science and cooking	As Candyce began to see that science was related to cooking, she began to consider other ways in which science could be related to her life.	Making connections to science in other contexts

These tables show how each Discourse theme found in Sharonda and Candyce's cases connects to scientific disposition that each learner developed as she participated in KSI.

The connections we are making between the Discourse identity and disposition frameworks enable us to begin mapping the building blocks of learners' dispositions that are typically studied individually (i.e., procedural and conceptual understanding, interest, social interactions, personal connections) to more overarching aspects of learners' development of scientific dispositions that are typically studied after development. This framework connection suggests a means of understanding how learners' dispositions develop as the result of shifting, integrated capabilities and values that form the building blocks for scientific dispositions. Additional research is needed, however, to understand how we might use such a framework connection to understand disposition shifts over longer periods of time and across diverse learners and learning contexts.

TABLE 5
Scientizing Progressions' Correspondence to Dispositions and Discourse

Scientizing Progression	Disposition Building Block Involved	Involved Discourse(s)	Candyce	Sharonda
Used science to accomplish personally meaningful goals	Interest (*curiosity)*	Chef Scientist	Connecting science and cooking to discover the why behind ingredients	Fixing cooking mistakes with precise measuring
Participation shifts	Social interactions (*community*)	Friend Scientist (Chef)	Engaging in science class with teacher	More active participation
	Procedural and conceptual understanding (*competence*)		Experimentation skills and application Knowledge about thickener effects	Measuring skills Consideration of the "process of things"
Values shifted	Personal connections (*commitment, seeing the value)*	Friend Scientist Chef Other contexts (i.e., home, school)	Craving for knowledge	Value of precise measuring Taking risks and making mistakes

This table shows how learners' scientizing progressions mapped to components of scientific dispositions previously identified and Discourses learners were participating in.

Implications: Designing Learning Environments to Promote Scientific Dispositions

Our analysis has several implications for the design of life-relevant science-learning environments that promote participants' scientizing. First, our findings suggest that enabling learners to "try on" science practices so that they can find roles that are personally interesting and relevant can be effective for promoting learners' development of scientific dispositions and identities. KSI gave learners opportunities to try out science participation practices, make mistakes, and learn from them. This is consistent with the call from educators for more opportunities for learners to engage in authentic scientific practices (Chinn & Malhotra, 2001; Osborne et al., 2003). Our work suggests that environments for promoting scientific dispositions should provide learners with opportunities to engage in authentic scientific practice in contexts of personal interest. Our work also suggests that this engagement outside of school where they have the time and support for trying on roles, making mistakes, recovering from them, and taking on scientific practices in their own ways is beneficial to scientific engagement. These findings also suggest that life-relevant science learning environments should offer the time and space needed to promote social experiences among the community of learners, facilitators, and science teachers. This is critical for exposing learners to new roles that they may want engage with in science and to help them feel comfortable taking on these roles.

Second, helping learners connect the science that they are learning in life-relevant science-learning environments to other settings in their everyday lives seems to be an important aspect of programs aimed at promoting learners' scientizing. We found that when we helped learners engage in science through activities related to their everyday lives, they used what they were learning in other relevant settings outside of school. Important aspects for facilitating these connections are tools that are accessible to learners in multiple settings. For example, measuring tools in KSI were particularly useful for helping learners make connections to cooking at home and science in school. Such connections seem to be particularly important for helping learners recognize and connect the concepts learned in well-scaffolded environments to everyday experience. Our findings also suggest the importance of designing activities so that concepts and practices learned in the life-relevant science-learning environment connect to areas of inquiry in science class (e.g., measurement, viscosity). This is also consistent with the recommendations of other life-relevant science learning-environment designers (Bouillion & Gomez, 2001; Fusco, 2001). Our work suggests that these connections can help learners begin to engage scientifically *outside* of the designed learning environment.

Our analysis also suggests that programs aiming to help learners make connections to science in other settings of their lives should especially help them make connections to everyday contexts that learners' peers and families are interested in. Analysis of the cases of Sharonda and Candyce shows that choosing relevant, everyday topics to use as a context for scientific inquiry provided an authentic link to larger audiences who could learn and benefit from scientific skills and knowledge of learners. This is consistent with Barab and Duffy's (2000) suggestion that communities of learners operate as a smaller part of a larger community and provides more specifics about how to achieve this goal.

None of this will work unless inquiries in the life-relevant science-learning environment help learners to make connections that are personally meaningful to them. When children are learning disciplinary content and practices in a context that is interesting to them as well as those around them, they have a wealth of opportunities for developing conceptual and procedural understanding, interest, social interactions, and personal connections to science. Cooking is an excellent context for a life-relevant science-learning environment because it is of interest to many middle-school age youth as well as their peers and families. When the topics that learners are investigating are interesting to them, they will want to engage and when they are also interesting to those that they interact with, learners have plenty of opportunities to do so.

Looking back at the descriptions of Sharonda's and Candyce's experiences in KSI, it might seem that the day-to-day experiences learners have in life-relevant learning environments are uneventful. However, over time, their individual experiences are building on each other in ways that enable learners to develop skills, knowledge, and curiosity that will powerfully impact their scientific dispositions. We think it is necessary for such development to involve inquiries that connect to learners' lives and their interests as well as time and space to build relationships and engage in variously dynamic scientific roles. Additional research is necessary to understand the specifics of making these environments work and how to sustain the long-term influence that these environments can have on learners' scientific participation and scientific identity. We look forward to learning how others will build on this work to add additional insight to these important issues.

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