Playing with Food: Moving from Interests and Goals into Scientifically Meaningful Experiences

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Abstract: As science educators, we want all learners to see the relevance of science to their lives and the world in which they live. Achieving this goal, however, has proven to be a difficult endeavor. Many learners see science as useful only in school, and they face difficulties connecting science to the real world and to their own interests and goals. In our research project, Kitchen Science Investigators, we aim to start with learners' interests and goals in cooking. We then help them connect cooking to science, using play to help them see food as an object of investigation. We then transition learners into engaging in authentic scientific practices. In this paper we present three cases that highlight scientifically meaningful experiences for KSI learners and the ways play, facilitation, and artifacts bridge the gap between their interests and scientific practices.

Introduction

As science educators, we want all learners to see the relevance of science to their lives and the world in which they live. Indeed, this is also a goal set forth by science education standards (Rutherford & Ahlgren, 1991). Achieving this goal, however, has proven to be a difficult endeavor. Many learners see science as useful only in school, and they face difficulties connecting science to the real world and to their own interests and goals (Chinn & Malhotra, 2001). Subsequently, many students are turned off by science. We therefore aim to understand how we can help learners see the relevance of science to their lives and enthusiastically engage in scientific practices. Success at answering this question is essential if we want more citizens to engage in public discussions about global climate change, stem cells, and other scientifically-relevant endeavors.

Researchers and designers of informal learning environments have found that starting with learners' own interests and goals presents opportunities for helping learners to engage in and to see the relevance of scientific, mathematical, and professional practices to their lives. Seiler (2001) created a science lunch group for African American boys in an underserved and underperforming high school around drumming and sports. For those interested in drumming, their discussions and investigations focused on topics such as sound frequency. For those interested in sports the conversations focused on laws of motion in physics. Nasir (2002) studied African American males' use of advanced mathematical understanding in the context of playing basketball to calculate their shooting statistics and to compare themselves to professional basketball players. Shaffer & Gee (2007) leveraged children's interest in video games to engage them in epistemic thinking and reasoning particular to a professional practice. They found that after playing one such epistemic game that required learners to act as urban planners, learners began to think of their own worlds in new ways. They also found that these learners thought in more complex ways about city planning. In each of these approaches, learners' interests and hobbies are engaged to help them move toward learning the "rules of the game" in some discipline or field they might join someday (Shaffer & Gee, 2007).

We, too, have created an approach to engaging more learners in science practices. In Kitchen Science Investigators (KSI), participants learn science and engage in scientific practice as they are creating and perfecting recipes (Clegg, Gardner, Williams, & Kolodner, 2006). Our afterschool and summer camp cooking and science program provides opportunities for learners, who may or may not be interested in science, to learn science through cooking. Our goal was to start with learners' interests and goals in cooking, help them to see food as an object of investigation through play, and then transition them into engagement in authentic scientific practices. We have seen this approach lead to scientifically meaningful experiences for our learners.

In this paper, we explore three experiences KSI participants indicated were scientifically meaningful to them. We seek to find out (1) What is a meaningful scientific experience to a middle-schooler who may not be particularly interested in science? (2)What scientific practices and accomplishments are supported by these scientifically meaningful experiences? (3) How can the having of such meaningful scientific experiences be promoted?

Of course, we cannot begin to answer these questions without defining some terms. To us, a *scientifically meaningful experience* is one in which learners derive meaning relevant to their lives from acting and thinking as scientists. In KSI, they do this through answering a question of interest to them, answering a question useful to themselves or to others, and through accomplishing a valued goal. Sometimes, they recognize the meaningfulness of the experience while it is happening; other times they don't recognize the meaningfulness until some time later when they are in a situation where what they have learned is valuable to someone else. We define *play* as voluntary engagement in recreational activities and less formal practices guided by learners' personal interests, curiosity, or amusement. Play is fun for participants, and during play, participants tend to be guided by trial and error. Science is more systematic than play, but play is often a good way to promote noticing and perspective taking. We find that we often encourage participants in KSI to play with their food so that they will notice attributes that they don't normally think about when cooking or eating. Then we help them move from playful participation to more scientific participation; we do that by helping them experience the value of systematically investigating attributes of food that they discovered during playful moments.

Background

Science education literature stresses the importance of going beyond teaching learners *about* science, but also helping them to see *how* science is done (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2001). In order to do this, we must get learners engaged in scientific inquiry by helping them to carry out scientific practices the way that scientists do. However, learners often do not engage in the scientific practices of professional scientists because classroom science emphasizes simple experimentation (Chinn & Malhotra, 2001). Helping them to engage in authentic scientific practice in the context of their own goals, we believe will lead learners to have scientifically meaningful experiences of their own. A scientifically meaningful experience has two components. First, a scientifically meaningful experience will involve learners engaging in scientific practice. Second, it is an experience that has personal meaning to learners themselves.

Scientific practices are those actions and pursuits relevant to scientific reasoning to test and explain phenomena. Such actions include, but are not limited to generating research questions, designing experiments to answer questions, controlling variables, making hypotheses and predictions, making observations, taking measurements, developing theories, and studying others' research (Chinn & Malhotra, 2001; Osborne et. al, 2001). While these actions may be encouraged in traditional classrooms, they are typically enacted in experimentation that is simple and fixed which is different from the experimentation of scientists. In contrast to simple science typically done in classrooms, *authentic scientific practice* that scientists engage in involves doing science (1) in the context of real-world problems, (2) where the full range of variables can be tested and the full range of outcomes may be unknown, and (3) where procedures for answering questions are chosen at least partially by participants, rather than being rigidly prescribed and ordered (Chinn & Malhotra, 2001; Gleason & Schauble, 1999a, 1999b). Authentic scientific practice thus includes, among other things, designing experiments and investigations to answer societal or real world questions, establishing rigor in these pursuits, and checking for the mistakes and misinterpretations of one's own work and the work of others.

A scientifically meaningful experience will not only involve scientific practice, but it will also be a personally meaningful experience for learners. Learners have much richer learning experiences when they can not only learn from the experience but when it also connects to their own interests, passions, and experiences (Resnick, Bruckman, & Martin, 1996; Shaffer & Resnick, 1999). We recognize personally meaningful experiences when learners use what they learned from the experience later and when they report deriving meaning for their own particular goals or interests from those experiences.

Based on our experiences, personally meaningful experiences for middle-schoolers often involve two forms of play: social play and physical manipulation. Talking, joking, laughing, and physical play that often occurs between friends and reinforces the social bonds between peers characterize social play. Play can also refer to tinkering that learners do with objects in the environment -- physically manipulating objects by touching, feeling, smelling, and/or pressing them. With respect to scientific participation, we have found some learners prefer designing experiments that specify actions to be done to objects in their scientific pursuits prior to beginning experimentation. Others prefer to design complex procedures that address problems that arise along the way by trial-and-error, tinkering with objects (Clegg & Kolodner, 2007). Both types of participation fit within the pursuit of science, but the latter is facilitated by playing with objects and can be harder to distinguish as scientific practice, especially when they are highly engaged in social play.

A scientifically meaningful experience will therefore connect a learners' scientific pursuit to their own interests, goals, and style of participation. Our goal then as designers and educators is to help learners participate in science in a manner that is authentic to the disciplines of science. In addition, we want to help them see scientific practices and their understanding gained as a result of engaging in those practices as relevant to their everyday lives, their interests, and their passions. Constructionist learning environments have been successful at designing tools that enable these types of meaningful experiences. Science and Math education literature has shown that these meaningful experiences can indeed happen in natural settings (Crowley & Jacobs, 2002; Nasir, 2002). Our work seeks to inform how we can design activities and facilitation support that enable these experiences in informal learning environments.

Design of KSI

Our goal in designing KSI was to engage learners in scientific practices through providing them with hands-on cooking and science experiences in an informal after school setting. KSI is informal, in several ways:

(1) participation in the program is not a requirement, rather, on a weekly basis participants have the choice to decide if they want to participate in the program and (2) there are no formal science or cooking standards we are trying to meet, thus (a) participants are able to choose how they contribute and what they learn, and (b) participants' are given choice in the recipes they prepare and perfect and in the direction of any given activity.

In order to design an environment where participants could learn to use scientific practices and pursue ideas that were personally interesting and motivating for them, we designed two activity sequences. First, KSI participants engage in a semi-structured activity sequence to familiarize and scaffold them in engaging in the scientific practices of asking questions, designing experiments, making observations, measuring, sharing results, and drawing conclusions. Second, participants engage in a flexible exploratory activity sequence where they can take the science they learned during the semi-structured activities to iteratively perfect recipes of their choosing.

The overall goal of the semi-structured activity sequence is to engage participants in conducting cooking and science experiments that are focused on understanding what makes foods rise or thicken. Learners and facilitators design experiments that highlight the effects of varying different amounts or types of ingredients in a recipe. The cooking experiments highlight the effects of ingredients (e.g., increased height, volume, density or thickness) in the context of the recipe they are preparing. During these activities, the facilitator helps participants develop a curiosity about the roles particular ingredients (e.g., leaveners and thickeners) play in their recipes by modeling how to use observations to ask questions and to design experiments to answer the questions raised. For example, participants make pudding with different types of starch thickeners and the facilitator helps them to make observations and compare the different textures and thicknesses of the thickeners. These experiments are designed as a whole group. In small groups, learners carry out each variation and then share their results, taste their dishes, and draw conclusions as a whole group.

Semi-structured activities are then followed by flexible exploratory activities called Choice Days where learners are given the opportunity to use what they have learned about particular ingredients to prepare recipes of their choice and make them come out with their preferred taste, texture, and mouthfeel. During these activities, learners have the opportunity to ask new questions, to practice using results and conclusions drawn from the semi-structured experiments to design experiments that answer their questions.

To help bridge learners' goals and the goals of KSI, we position learners first as chefs who want to understand how to make their recipes come out with the desired taste, texture, and mouthfeel. We then transition them into being investigators, who are curious about the roles that each ingredient plays in making their recipes come out as desired. Last, we help them use scientific practices to find answers to their questions about particular ingredients so that they can make informed decisions about the ingredients they use in preparing their dishes. To help them make these transitions, we encourage learners to play with their food as a means of developing more questions, observing their results, making comparisons across variations, and building understanding of scientific phenomena through engaging in scientific practice.

Methods

Data Collection

The cases presented in this paper were taken from data collected in our most recent enactment of the KSI program. The program was implemented as a one day a week after-school program as part of a larger weekly after-school initiative by a local YWCA to engage teen girls in science and technology related activities. The participants in the study were from the same suburban middle school where the population was 99% African American. Thus, all participants were African American girls in 6th – 8th grade. Participation varied over the 9-month period, but we had 15-20 consistent participants (7-9 6th graders, 7-10 8th graders, one 7th grader). The program was led by a team of 3 facilitators: the authors and the school program coordinator. For each session, we collected and transcribed video recordings of each group. In addition, after each session we recorded post-observation field notes that captured the significant learning events that occurred during the session. As a part of Tamara Clegg's (Tammy) dissertation on learning and identity, we also conducted and transcribed interviews with four focal learners, their parents, and their science teachers at multiple points during the implementation and once after the implementation ended.

Case Selection and Data Analysis

The analysis for this paper emerged from a trend Tammy discovered while analyzing the data for her dissertation in the context of exploring the participation of individuals and roles they took on in the program. In particular, she noticed that the roles individuals took on were impacted by the impromptu side investigations participants engaged in and the physical observations they made during these investigation. After noticing this trend, she intentionally identified all the side investigations and physical observations made by small groups of individuals in her data set. She then selected five particularly salient instances of these practices where scientific practice was enhanced and where learners showed or reported deriving personal meaning from the experience. To establish validity, she then presented these instances to the second author, who reviewed the transcripts and videos to ensure they were representative of scientific practices and personal meaning for learners. From these, three cases were selected based on the range of scientific practices participants engaged in and the strength of evidence from transcripts and interviews that suggested the practices were useful and meaningful to the participants. With the unit of analysis being the small group, we then coded each case for instances when groups engaged in the following scientific practices: asking questions, making observations, making explanations of scientific phenomena, sharing results with others, and drawing conclusions.

Case Studies

As you read the three cases that follow, notice that Cases 1 and 2 represent the ways in which participants initially engaged in simple scientific practices in KSI on Day 12, while Case 3 characterizes the ways in which they engaged in more complex scientific practices on Day 20, the last day of the thickeners unit. Also notice how the facilitation and artifacts in the environment promoted participants' engagement in the scientific practices modeled.

Cases 1 and 2 occurred on Day 12, two days into the "thickeners" unit. On this day, the main activity was a pudding experiment where each group made pudding with a different type of starch thickener to learn about the variety of textures each thickener created. At the beginning of this session, Tammy, a facilitator, provided an overall framing of the types of scientific practices that the participants would be engaging in: making observations, taking measurements, conducting systematic and precise experiments, and sharing results. Following this framing, she introduced the Food Tasting Activity, an activity we designed to help the learners make objective, descriptive observations about food. This activity was meant to prepare participants to notice the differences in texture and thickness of the puddings they were going to make in the subsequent activity.

Case 1: Describing, Comparing, and Testing Different Store-bought Puddings

The initial big group activity for Day 12 was the Food Tasting Activity. For this activity, we brought in 15 store-bought desserts and pastries with pudding-based fillings for participants to taste, describe, and compare. We felt this activity was needed to help participants develop imagination about the kinds of complex dishes they wanted to prepare (dishes that combine different ingredients and textures) and to help them develop objective ways of describing and comparing dishes. Our goal here was to move learners from simply sharing their opinions about the tastes and textures of food (e.g., it tastes nasty) to making descriptive observations of particular properties of the taste, texture, and mouth feel of the foods (e.g., it is smooth and thick).

Unfortunately the simple act of tasting the foods was not enough of a catalyst to get participants to make descriptive observations of the food they tasted, even when prompted. For one group of participants, however, a major turning point in the activity occurred when Treeva, bored with tasting the food, and probably satiated, said, "I'm sick of eating this right now." In response, Christina, the facilitator, suggested that they focus on testing and comparing the foods instead of eating them. The girls then began looking at different foods on the table and commenting about their thickness and describing in more detail what they liked and didn't like about the foods they were tasting. After tasting the tapioca, Mercedes said she didn't like the way it felt in her mouth. This prompted Candyce to say that she didn't like the flavor because it was sort of lumpy. Mercedes then agreed that she didn't like the feel of the tapioca balls either.

Not yet satisfied with the level at which the girls were comparing the thickness of the foods, Christina, the facilitator, shifted the activity to helping the girls find ways to describe the texture. She suggested developing a test for thickness. In response, Mercedes, who was dipping her spoon in and out of a cup of pudding and watching how it fell off the spoon, suggested testing the thickness by using a spoon to measure how long a particular food stayed on the spoon when turned over. The test sparked Candyce's interest, and she began suggesting foods to try in this test. The two girls then began playfully placing samples of the puddings and fillings on spoons and turning them over at the same time to see which one fell first. Christina then prompted the girls to use this test to rank the food on the table by thickness. She helped them interpret the meaning of their test with respect to the speed in which it fell and which fell first. The girls concluded that the pudding that fell from the spoon first was thinner than the one that fell last. Observing their tests, the eighth grade participants on the other side of the table began to do the spoon test as well. Intermixed in their testing, Candyce and Mercedes started playful competitions based on their predictions about which foods would stay on the spoon longest and which would be the thickest in the ranking. Included in their predictions were descriptions about how the foods looked and smelled. While they ran the test, Christina helped the girls use the results to rank the foods by thickness by rearranging the food artifacts on the table. Once they completed their rankings, the girls enthusiastically demonstrated their spoon test and shared their results with the rest of the group.

Candyce later remembered and recalled her experience with the store-bought fruit tart during the food tasting activity as not particularly pleasant because of its color. In recalling this experience, Candyce without prompting used a descriptive observation about its color to explain why she did not prefer to make her own fruit tart. During later sessions, these learners also became more consistent in making descriptive observations. For example, on Day 20, as you will see in Case #3, Candyce's described the buttermilk as "creamier and thick," and this descriptive and comparative observation led her to wonder about the difference between buttermilk and milk, which, in turn, initiated a buttermilk vs. milk experiment to figure out the answer.

Case #1 Discussion

What made this episode scientifically meaningful to the participants? Candyce's recollection of the fruit tart indicates that she used her observations about the foods to reflect on the types of foods she would be interested in eating again or preparing herself. We also know that this case was scientifically significant for Candyce because we can see that she learned from it. At the beginning of the Food Tasting Activity on Day 12, she, like the other participants, was having difficulty making descriptive observations and comparisons because they were simply focusing on tasting and eating the foods. However, by the end of the episode the girls were making more descriptive observations as a result of engaging with the food as an object with properties that could be tested and ranked.

How did the enactment promote this? First, the facilitator allowed participants to engage in the activity as it felt most natural to them, i.e., through playing with and tasting the foods. Then the facilitator recognized a shift in the participants' interest and participation, from interested to bored, and she used this as an opportunity to refocus the participants' attention onto the scientific practices of testing, making observations, and drawing conclusions. Specifically, the facilitator transformed their play practice of dropping the pudding-based foods from spoons suspended in the air into a more formal test for ranking the thickness of the foods they tasted. The facilitator's ability to create an authentic opportunity for engaging the participants in these scientific practices was also created by the availability and diversity of artifacts, namely the pudding-based foods with varying degrees of thickness for which the crude spoon test would produce noticeable differences in the time it took the pudding to fall. In addition, the facilitator played a major part in structuring the activity by keeping track of results, and using the artifacts themselves to represent the rankings the participants were developing and making the rankings available for participant inspection. This representation of the rankings (the puddings lined up according to how thick they were) allowed the participants to confidently share their results and procedures with other KSI participants.

Case 2: Viscometer Test

Following the Food Tasting activity, the learners divided into small groups to do a simple cooking experiment. Each group made a simple vanilla pudding recipe but used a different type of starch thickener. The over arching goal of the activity was to understand why foods have a range of textures and thicknesses and the roles starch thickeners play in creating those difference. Thus, we wanted the learners to make objective (descriptive and quantitative) observations of the differences in thickness of puddings with different thickeners, so that they could use what they learned to make more complex dishes similar to the ones that they tried earlier during the Food Tasting activity. To achieve this, we planned to have learners measure their pudding with a tool called a *viscometer* that measures the viscosity or thickness of liquids. Using a viscometer, the girls would be able to measure, in seconds, how long it took for the pudding to flow through the opening in the bottom of the viscometer. While the spoon test they had developed during the food tasting activity allowed learners to rank thicknesses and to characterize the thickness qualitatively; the viscometer allowed them to measure thickness quantitatively.

Measuring the thickness of their pudding was difficult because the girls did not finish making their pudding until near the end of the session. They had to wait for it to cool before putting it through the viscometer, and they were running out of time. However, Tammy saw that some of the group members were not as active as others on this team during the pudding preparation. She therefore encouraged those who were not busy with the pudding to measure the viscosity of milk while their pudding was being prepared. Candyce and Mikayla responded to Tammy's prompting and Tammy showed the two learners how to set up and use the viscometer. When the facilitator asked what they thought would happen, Candyce predicted that the milk would come out more slowly than water because milk is "sort of thick," as compared to water.

As they were waiting for their pudding to cool, Amber asked to take a parfait home. Amber's interest in the pudding made Tammy realize that although they could not measure the viscosity of their pudding right then, they could measure and compare the viscosity of other foods they had tasted and examined earlier. Tammy suggested that they try measuring the parfait with the viscometer to see how its viscosity compared to their pudding. When Tammy brought the parfait for measurement, Candyc, promptly took the parfait and began setting up the measurement with Amber. As they measured, Amber excitedly called Tammy over several times because the parfait was taking much longer to come out of the cup than she expected.

Since the girls were able to stay late, they were able to measure the viscosity of their pudding once it cooled. As they set up the viscometer to measure the pudding, Amber and Candyce made predictions about how long it would take. Amber thought their pudding was thicker than the parfait, so it would take the pudding longer to flow from the hole in the viscometer. As they began the measuring the pudding, they were surprised to see that the pudding was not coming out of the viscometer at all. One group member joked that they could walk up and down the hall for an hour and the pudding would not go anywhere. Mikayla excitedly suggested that they try it. Amber suggested they walk up and down the hall three times. The facilitator permitted Amber, Mikayla, and Precious to carry out their test while Candyce held the viscometer. Upon returning, Amber immediately checked the viscometer and said, "Okay, it's still not done, is it?" When she saw that no pudding had flowed from the viscometer, she exclaimed, "Knew it!"

Later, we learned from Amber that she told her science class about her experience measuring viscosity in KSI when they discussed the topic of viscosity in class. She also talked about the viscometer test, three months later, on Day 20, when the idea of viscosity came up in presentations to their parents. Later, during an interview, she told us that the viscometer measurement was something that she did as a scientist in KSI.

Case #2 Discussion

What made this episode scientifically meaningful to the participants? Participants were able to move from descriptive observations to quantitative representations of thickness when encouraged by the facilitator. In this way, learners were moving from simpler forms of scientific practice (i.e., making observations and predictions) to a more sophisticated form (i.e., using observations to support predictions, initiating their own tests, and designing creative ways to explore their predictions). Amber seemed to be proud of these accomplishments and to see them as scientific, as evidenced by the three different times we recorded her sharing the viscometer experience and its significance to her with others.

How did the enactment promote this? Initially, the facilitator recognized the opportunity to engage learners in the scientific practice of taking quantitative measurements to compare thicknesses of the pudding, yogurt, and milk. She saw these opportunities when the participants (1) were bored and (2) were interested in tasting a new dish. Then she introduced learners to quantitatively measuring thickness by showing them how to use the viscometer to take a scientific measurement of thickness. Finally, the facilitator's recognition of the availability of the viscometer, milk, and parfait prompted their impromptu comparison of the thicknesses. It is also important to notice that the parfait was available and accessible from a previous activity (the beginning food tasting discussion) even after its intended purpose was past.

Case 3: Milk vs. Buttermilk Investigation

Day 20 was the final day of the program, in which we invited the learners' parents and family members to come for an open house during the second half of the session. On this day, we wanted participants to use their knowledge of leaveners and thickeners to revise a recipe of their choosing to achieve their personal goals for the dish. Candyce, Treeva, and Rachael decided to make chocolate cake. Prior to cooking, they thought a little about the leaveners and thickeners they would use in their recipe, but it was not until they were baking and wondered about the difference between buttermilk and whole milk that they really began to think about leaveners in their cake.

As Candyce and Rachael measured buttermilk for their cake batter, Candyce, noticed that buttermilk was "creamier" and "thicker" than milk. She asked about the difference between buttermilk and whole milk. Tammy told her how buttermilk is made and that when buttermilk and baking soda are mixed, a foaming reaction happens. Then, when she realized that we had milk, buttermilk, and baking soda available to help her demonstrate the reaction, she began to set up what she was describing. As Tammy measured the baking soda and whole milk, she asked Candyce and Rachael what they thought would happen. Rachael predicted that the mixture would not bubble up. After adding the milk to the baking soda, they saw that nothing happened.

Switching to the next variation, Tammy asked what they thought would happen when they added buttermilk. Rachael thought it would bubble. Tammy reminded the girls about the baking soda and baking powder experiments they did several months before, and she asked them what type of ingredient they needed to mix with the baking soda in order for it to begin producing air. Treeva remembered it needed an acid. When Tammy poured the buttermilk in the glass, they were surprised to see that nothing happened to the mixture at first. Tammy then noticed something at the bottom of the buttermilk glass and they saw the mixture start to bubble up. Amazed at the size and look of the bubbles, all the girls leaned in over the table to see what was happening in the glass. Treeva picked up the buttermilk glass and asked, "What is it doing?" Candyce made the observation that there were bubbles at the top and that it was foaming. Based on their curiosity about the reaction, Tammy explained that the mixture was producing air, meaning CO_2, because buttermilk is an acid. Treeva, became excited by the smell of the mixture; she and Candyce agreed it smelled like baby milk.

As the group continued making the cake, they periodically noticed changes in the smell and look of the buttermilk glass, playfully making observations about it. At one point, Candyce noticed the glass sitting on the table and excitedly said that it looked strange, noticing that the baking soda seemed to settle on the top of the buttermilk. She dipped her fingers into the cup and walked over to Treeva (who was mixing the cake batter), showing her the buttermilk mixture on her finger. Later, when Candyce mentioned throwing the mixture away, because it looked "creepy," Tammy told her she could save it and show their parents in their presentations.

During presentations to their parents, when the facilitator mentioned baking soda and baking powder, Candyce immediately brought up their experiment they had done and walked across the room to get their buttermilk mixture to show the parents. She and Rachel reminded facilitators of the experiment during the presentations when they were about to move on to the next group without allowing them to discuss it. With prompting from Tammy, Candyce explained the concept of leaveners, and Rachael and Candyce described their experiment and results. Afterwards, Candyce moved around the room showing each audience member and fellow KSI members the buttermilk mixture. Later, in a subsequent interview, Candyce used the buttermilk and baking soda experiment as an example of how science has helped her figure out why things happen in recipes:

> Candyce: okay if you have some ingredients, and let's say you mix them together, but something happens and you don't know what it is, then that's where science can help you. You can figure out like why this happened. Like say you mix, baking soda and buttermilk together. You could say like this happened because buttermilk is an acid.

Case #3 Discussion

What is scientifically meaningful about this enacted activity? Learners engaged in the scientific practices of asking questions, making observations, and monitoring results. These experiences also contributed to their understanding of leaveners (as evidenced by their later explanations). We also see that this experiment was meaningful for learners in their continued interest in the artifact even after seeing the initial reaction. For example, they initiated and sustained discussion of the experiment later with their parents. We also see that reflection on the experiment in subsequent interviews helped Candyce see the connection between cooking and science.

How did the enactment promote this? First, the facilitator recognized Candyce's curiosity about buttermilk as an ingredient. Then she recognized this curiosity as an opportunity to provide the appropriate prompts, explanations, and experiments to help the group answer their questions. Next, she modeled the practice of using experiments to make explanations by leading an experiment using available materials to show learners the differences between buttermilk and milk. She also gave learners opportunities to participate in the experiment by prompting them to make predictions and discuss what they already knew about the ingredients. Again, the diverse artifacts we had available for this experiment also enabled the experience. Although their recipe did not call for whole milk, it was still available in the environment and the facilitator was aware of that when she initiated the experiment. Furthermore, the unusual reaction of buttermilk with baking soda enhanced leareners' interest in making observations and later sharing their results with the whole group and their parents.

Discussion

What is a scientifically meaningful experience for middle-schoolers? Earlier, we defined scientifically meaningful experiences as ones in which learners make scientific accomplishments that have meaning relevant to their lives. Over the span of the three cases presented here, we see that learners were able to participate more authentically as scientists over time, in that they began to make predictions and descriptive observations, using descriptive observations as evidence for their predictions. Learners also made quantitative measurements of their results (i.e., their dishes). Finally, they were able to make scientific explanations, sharing their results with others. Chinn & Malhotra (2001) suggest that these practices are authentic to the practice of scientists and should be promoted in school science. Here we illustrate how an informal environment supports middle school learners in engaging in these practices. Relating these accomplishments to learners' lives, we see that learners were able to share their accomplishments with their peers and parents. In subsequent interviews, we see that these accomplishments contributed to learners' reflections on their participation in science and on the relevance of science to cooking. Thus, the scientific accomplishments learners made in the context of their everyday lives helped them to think about their role in science and the relevance of science in their lives.

When does our design promote the having of meaningful scientific experiences? We can see from our results that it is hard to predict when learners will begin to ask questions and make connections from explanations. Intended goals were not always realized when we expected them to be (if at all), but many were realized over time. Even as they were, they did not happen in the way we expected, nor the timeframe, as we might expect based on Crowley & Jacob's (2002) work. In KSI, the design of earlier experiments and activities was intended to provide common experiences to refer back to over time to help learners perfect their recipes. Facilitators were able to guide participants back to thinking about these experiences later because all activities were designed to contribute to participants' achieving a larger goal that learners had and because learners were aware of what each activity could contribute to achieving that goal. For these reasons, it was natural for facilitators to bring learners back to those experiences at relevant moments, just as Crowley & Jacobs (2002) advise. But, while Crowley and Jacobs help us understand how to use timely opportunities to provide children with explanations and to help them connect across experiences, our work uses the same ideas to suggest ways of finding timely opportunities for learners to explore answers to their own questions and use those experiences to help them connect their experiences.

How can we promote the having of those experiences? This work offers a glimpse into the underlying mechanisms of facilitator support and artifacts in an informal learning environment where facilitators may be less aware of participants' attention, interests, and curiosities than a parent might be with their child while visiting a museum (Crowley, 2002). Yet, in the cases we presented, facilitators were able to recognize times when learners' interests and attentions were piqued and when they were dwindling. They were then able to capitalize on these moments, using them as opportunities to engage learners in unplanned scientific activities by selecting the appropriate scientific practices for the given moment. Keeping track of learners' interests and attentions and the learning opportunities available may seem like an impossible feat. However, when working with small groups of learners, facilitators can often build off of the interest of one participants to help others become interested and engaged.

To promote such unplanned scientifically meaningful experiences, facilitators must also be equipped with the necessary artifacts to help the learners increase their understanding, familiarity, and experience with the scientific practices (e.g., the puddings with a range of textures). And they must take advantage of the opportunities for piquing interest when the opportunities arise rather than waiting for lulls in activity. Our work shows that, unlike museum visits or home explanations, artifacts do not only trigger the explanations; they can also be used to engage learners in building, interpreting, and applying explanations.

Conclusions

We presented an approach to helping participants learn and practice science in the context of their own interests and goals. The approach led to scientifically meaningful to experiences for learners. We found that helping learners to play with artifacts promotes learners' engagement in authentic scientific practices and meaningful experiences. But these experiences must be grounded in the context of a larger goal that learners have, and facilitation is needed to orient learners' practice with the objects, helping them to explore and investigate in meaningful ways. More work is needed to understand the complexity of these learning environments and to understand the impact these meaningful experiences have on learners' identities and views of science.

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