

# Promoting Learning in Informal Learning Environments

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**Abstract:** Learners need to see the relevance of their learning in their everyday lives and activities in order to understand and value the importance of learning. To do this, they need rich experiences that promote such learning and mental model building. So how can we promote substantial learning in everyday, informal environments from real world practices and experiments? Museum learning and some after-school environments have addressed this issue, but in many cases, the learning can only go but so far. This paper seeks to explore how we can promote learning in these environments that can be transferred to other places and experiences. Kitchen Science Investigators (KSI) is a research endeavor, aimed at creating an after-school environment where elementary and middle school children learn from everyday experiences. This paper tells the story of the learning that occurred in this environment, pointing out activities and artifacts that worked well at both motivating and promoting learning.

## Introduction

Family experiences provide rich venues for informal learning when parents interact with children, helping them to develop and sustain their interests and have experiences that help them learn (Crowley & Galco, 2001; Crowley & Jacobs, 2002). These experiences effect how they interact with the world later in life – the quality of their thinking, their identities as learners and their feelings about learning, etc. (Crowley & Galco, 2001; Shaffer, 2004a). But the opportunities children are exposed to depend on their connections to adults who have the time, desire, resources, and ability to help them. Children with less access to these types of connections may have a hard time identifying or pursuing interests they might otherwise develop, especially those related to science interests that may also help them develop general critical thinking and reasoning capabilities. Too often school instruction in those areas is too formal and didactic to generate their interest. The result is that many children do not develop serious interests and passions until late in their schooling, some never having the opportunity at all. Without getting to real depth in learning and applying at least some area of understanding, it is difficult to learn to think critically or to learn how to learn (Linn & Muilenburg, 1996).

One way to address these problems is by changing schooling, but school is not and should not be the only place available to develop children's interests, capabilities, and understandings. Another way to address the idiosyncrasies in the opportunities that children have available to them is to develop a variety of public informal learning venues. Museums, after-school programs, church groups, and others have been developed with this need in mind. But participants in such informal learning activities do not always attend regularly or spend enough sustained time in these programs for serious knowledge construction. Most informal learning environments tend to be places where seeds of interest are sown (Wellington, 1990) or where a learner's already-established islands of expertise are enhanced (Crowley et al., 2002), rather than being venues where sustained learning leading to conceptual understanding is easily afforded and promoted.

Substantial learning requires significant time. Therefore promoting learning in informal learning environments requires finding ways to sustain motivation and interest while promoting construction and refinement of conceptual models (Crowley & Jacobs, 2002). Kitchen Science Investigators (KSI) is a research endeavor aimed at creating an after-school environment where elementary and middle school children learn from cooking experiences. This paper tells a story of learning that has occurred in this environment, pointing out activities and artifacts that have worked well at sustaining interest and promoting learning.

## Background

Learning means increasing and revising knowledge and capabilities (Greeno, Collins, & Resnick, 1996). Learners extend their knowledge by continually and thoughtfully incorporating lessons learned from new experiences into their knowledge bases. The mental models they construct help them explain how things work, and

they use them with lessons learned from experience to make and test predictions (Collins, Brown, & Newman, 1989). To construct accurate mental models and to be able to extend their use to new contexts, it is important for learners to work on real and varied problems, to experience the results of decisions they make, and to be able to explain discrepancies between their predictions and those outcomes (Blumenfeld et al., 1991; Greeno, Collins, & Resnick, 1996; Kolodner, 1997). When learners value learning, they are motivated to learn and use more self-regulation, as well as cognitive and meta-cognitive skills (Blumenfeld et al., 1991; Bransford, Brown, & Cocking, 2000).

Informal learning environments have traditionally focused on motivating learners to learn through exploration (Wellington, 1990). Much of the research on informal learning focuses on museum science learning. Museum learning has generally been designed to give learners access to the science that explains everyday events and objects, providing opportunities to connect abstract science concepts with concrete real world objects and situations, and promote interest and motivation (Crowley & Galco, 2001; Wellington, 1990). Crowley and Jacobs (2002) found that this is most impacting when parents attend museums with their children and help them use the museum experience to build upon their existing *islands of expertise* (topics the child has shown interest in and knows something about) and help them develop new ones. After-school environments are also difficult places for promoting deep learning. Computer Clubhouses, designed by Resnick et al. (1996), are places where inner-city youth and adult mentors work together on projects. The goal is for children to learn to express themselves fluently with technology tools (Resnick, 1998). Though there are some compelling success stories, cases of sustained deep-level investigation remain the exception rather than the norm (Zagal & Bruckman, 2005). As in museums, without guidance from a coach, childrens' exploration is usually limited.

In order to help learners understand and value the importance of learning from everyday experiences, we need to promote transferable learning among more participants in informal learning venues. Our research seeks to use cooking experiences to promote the development of scientific conceptual models and of scientific reasoning capabilities. We aim to explore the types of artifacts and activities will work best in promoting such learning.

### **Our Approach:**

Kitchen Science Investigators is an after-school club. Learners actively participate in cooking and baking with the goal of learning scientific principles behind successful cooking, and practicing reasoning skills required for revising and adapting recipes. As an after-school program, KSI is not bound to a set curriculum or assessment requirements. It can take advantage of social interactions for motivating learning the “hows” and “whys” of the subject at hand (Wellington, 1990). Learner motivation and engagement are high priorities in the design of KSI, but we also need them to take part in activities that promote science learning and expert scientific practices. To meet these needs, we have integrated the guided inquiry of problem-based learning (Koschmann et al., 1996) with more open-ended inquiry of project-based learning (Blumenfeld et al., 1991), traditionally enacted in formal classroom settings (Barron et al., 1998). In KSI, learners progress from structured activities that scaffold their ability to plan experiments, draw conclusions, and construct conceptual models (problem-based cooking and chemistry experiments) to more free-form and complex tasks such as modifying recipes for desired results (project-based activity called “Retry Days”).

During the structured activities, participants engage in a “cooking experiment”. They also carry out a “chemistry experiment” that highlights the same scientific concepts featured in the corresponding cooking activity. The aim here is to help learners make connections between the cooking and the chemistry experiments. Cooking experiments involve all groups, and requires them to prepare the same dish. Each group, however, has a different ingredient or different quantities of a selected ingredient. Learners examine differences in the products of their cooking and determine what happened as they prepared their recipes. Chemistry experiments are shorter and “cooler.” Here, learners’ explore the roles of particular ingredients as a way to help them build conceptual models regarding the chemistry (e.g., How do eggs effect brownies?). Later, during a Retry Day, a range of variables can be tested, the outcomes are unknown in advance, and the recipe procedures and their sequence are not rigidly prescribed in the true form of scientific inquiry (Gleason & Schauble, 1999). Young learners however, have trouble developing and completing the necessary sub-tasks required for such scientific inquiry. When parents were asked to help with this process, they are often effective at helping their children generate evidence and less so at helping them interpret their evidence (Gleason & Schauble, 1999).

In implementing KSI, we paid attention to practical design issues as well. We recognized the importance of integrating whole-class discussions with cooking and science activities, to give children a chance to articulate what they had learned and to make sense across the variety of activities (Kolodner et al., 2003). Because some of the complex chemical reactions are difficult for ten and eleven year old learners, we focused the content on leavening agents, allowing other concepts to fall out of that exploration, without expecting learners to understand or even see all chemical processes going on in their baking.

## Our Studies

The study was conducted after school, in ten 90 minute sessions held in the small cafeteria of a private school. Sixteen fifth graders (8 male, 8 female) participated in the program, monitored by three facilitators (two regulars and one “part-time”). An “occasional” facilitator recorded field notes and helped learners when necessary. Two facilitators (the first two authors of this paper) and a fifth grade science teacher led group discussions, answered questions, and prompted learners for scientific observation and reflection during experiments. During the first few weeks, the KSI learners did cooking experiments with pizza, brownie, cookie, and cake recipes, and carried out corresponding chemistry experiments. They explored chemical reactions that take place with yeast, eggs, baking soda and an acid vs. baking powder, and gluten. During three “Retry Days” (weeks 5, 8, 9), they changed ingredients and procedures in previously used recipes to further explore these science concepts. We collected video data, field notes, and learner artifacts to analyze scientific reasoning, using a two-pass approach.

We used a qualitative approach to analyze the video data and field notes. First, we examined the video data to identify instances of scientific reasoning and contexts in which it occurred. In this pass, we identified instances of scientific reasoning and activity sequences. In a second pass, we looked at all the instances of activity sequences identified in the first pass to find instances of scientific reasoning we might have missed and instances where children missed opportunities for scientific reasoning. We used field notes and artifacts to triangulate our findings.

## Results

We present our results as a case study, telling one particular compelling story. The story of pizza and yeast presents several examples in which students learned content, strengthened reasoning capabilities, and transferred their learning to new cooking situations. We begin by presenting results from the learners’ initial day in the program and progress through other key sessions during which learners built upon their conceptual models of yeast and other leaveners.

### Day 1: KSI Intro

On the first day of the program learners had a short discussion where they looked at the differences in different types of breads and crackers that were provided to get them thinking about “leaveners” (e.g. baking powder, yeast, etc.), and their effects on the finished product. All groups then prepared pizza dough using the same recipe. To observe the leavening effects of yeast in their pizza, learners did a “Yeast-Air Balloon” science experiment where they combined yeast, water and sugar in a water bottle and secured a balloon on top of the bottle. Learners were amazed as they began to notice their balloons inflating. They continued to closely monitor their bottles and balloons for more changes. Seeing the inflation of other groups’ balloons, one group wondered why their balloon had not yet inflated. As they attempted to debug their experiment, they figured out that the water they used was too hot and had killed their yeast. They redid the experiment, making sure to precisely measure the water temperature. They learned the importance of precision in following a procedure and that there is a real difference between warm and hot, particularly when using yeast. They brought this to everyone’s attention during the large group discussion:

Adam<sup>1</sup>: *Well actually, this one messed up because the water was too hot, which made it not foam up, and this one, we got it at exactly the right temperature. If that was too hot, it wouldn’t foam up and make the air go into the balloon, so this one we got it right down to the um 115[ °F].*

Another example of reasoning about their experiment results centers on the balloon of one group of students inflating more than the other balloons. This group knew they had added more sugar than the procedure called for, and they conjectured that this was the reason their balloon inflated more than those of other groups:

Elijah: *For ours, we had it all at 118 degrees [Fahrenheit], we put in one teaspoon of sugar accidentally [instead of one tablespoon]. After that we put in two more tablespoons, so we had a lot of sugar. And the yeast kept multiplying. And it’s way up here.*

## Day 5: Pizza Retry Day

On Retry Days, learners decided which cooking activities or science experiments they wanted to do. We asked them to make changes based on science they learned in previous sessions. On the first Retry Day, all of the groups chose to try to improve on the pizza dough recipe, generally aiming to make it flatter or thicker. Based on their previous experiences in KSI, most groups increased or decreased the amount of yeast, sugar, and/or water (refer to Table 1). One group (Group 2), however, replaced yeast with baking soda and baking powder, which also required procedural changes to the recipe. Learners were aware from a previous KSI session that baking soda and baking powder activated with water and that immediately after activating, it produced air (faster than yeast and water). One group member explained it this way:

Julia: ... we wanted to see if maybe we could add all the dry ingredients in first, because if we add the water and flour first, all the carbon dioxide would just go in the air and flour is supposed to act like a balloon and capture the carbon dioxide and see if it's gonna get bigger or thinner.

Table 1: *Retry Day 1 Changes to Pizza Crust Recipe*

	<b>Group 1</b> (Elijah, Jalon, Jacob, David)	<b>Group 2</b> (Julia et al)	<b>Group 3</b> (Rachel et al)	<b>Group 4</b> (Adam, Darius et al)
<b>Science Question</b>	How much more will the pizza rise with twice as much yeast and sugar?	What will happen if we use baking soda and baking powder instead of yeast?	What does less yeast do to make the pizza different?	How big will it get? Will it pop?
<b>Recipe Change</b>	Double the yeast and sugar	Replace yeast with baking soda and baking powder. Add all dry ingredients first, then liquids.	½ amt. of yeast ¼ Tsp. less sugar ¼ Tsp. less water	Double yeast ½ cup more water
<b>Prediction</b>	Pizza will be twice as tall	It will rise more than the yeast makes it rise	Will make it flat, not as high (Sugar and water make it rise)	It will get huge because yeast makes it rise

Because each group changed something different in the original recipe, we asked each to reserve a sample of their uncooked dough for observation, placing each “dough ball” on a labeled tray. Our expectation was that learners would compare their dough balls. We were pleasantly surprised by the extent of their scientific reasoning when they made these comparisons. Once all of the dough balls were placed on the tray, learners immediately began to pick the dough balls up, feeling, pressing, and stretching them. As they did this, they were making observations about how the dough balls felt using terms like “squishy” and “rough.” Soon, learners began to rank the doughs, placing them in numerical order, first based on what dough was the “best,” later based on more specific criteria such as which dough balls were “taller” or the “fluffiest.” A few learners began to make predictions about their own and others’ pizza outcomes (e.g., Julia: “I think ours is going to rise the most”; Jacob: “It’s definitely gonna rise the fastest”). As learners came in and out of the work area, they asked one another to feel different dough balls (e.g., “Feel ours, and we’ll feel yours”). One facilitator prompted learners to think about what might be wrong with one group’s dough when a learner observed, “Well this [dough] is kind of too sticky.” The learners concluded that it had too much water and that more flour should have been added (a technique they learned when making the original pizza recipe). In another instance, learners became so engaged in the activity of playing with their dough balls and discussing the science that a group of them spontaneously decided to tell one of the cameras what they learned.

Adam: ... I learned, that if we put more yeast, it will grow really lar- thick (hand motions). And if we put it in warm water, it will pop bubbles.

Jacob: yeah, but it’s really sticky.

Jalon: And, but if you add more yeast, you need more sugar for it to eat.

Adam: No you don’t! Because we put warm water in it and it pop bubbles.

Julia: If you don’t add any yeast at all and add baking soda and baking powder instead, it makes it soft, smooth, and it makes it taste better.

Darius: Ours is so much better!

Rachel: Wow, this is fun!

When a facilitator tried to get learners to sit down together for the formal group discussion, one learner yelled, “BORING.” Yet throughout the entire discussion, he remained fully engaged in scientific discussion as he played with the dough balls. The group discussion at the end of every KSI session never truly became *one* discussion on this day. Learners continued to toss the balls around, intermittently joining the big group discussion while still talking about the dough balls in their small groups.

### **Day 8: Retry Day 2 (Cookies With Yeast)**

During the next Retry Day, one group continued to investigate the effects of yeast, using yeast to make cookies. In planning the cooking experiment, the group decided to replace baking soda and baking powder with yeast. The hypothesis for this experiment was that the yeast would make the cookies rise more than baking soda and baking powder and that the cookies would be “more fluffy because air bubbles would form.” The group also planned to add a rise time for their dough and to knead it if it was “kneadable,” as they did with other yeast recipes.

As they began the activity, the learners knew they needed to use warm water to “wake the yeast up” and sugar for it to “eat”. They mapped this to their cookie recipe, recognizing they needed to add warm water to the ingredients. But they weren’t sure how to integrate the sugar, as the original recipe did not call for white sugar. They asked a facilitator who informed them that the yeast could indeed eat the other types of sugars. They were also unsure of where mixing the water and yeast fit into the sequence of the procedure. The recipe called for separating dry ingredients and adding those later. However, they knew that the yeast needed water to be activated. Realizing this, they sought the help of a facilitator again:

Elijah (to facilitator): We’re supposed to get all the dry products, so should we put water in a different bowl from the yeast and then add it later?

The facilitator explained that the water and yeast needed to be combined separately. The student then inquired as to where the sugar should go. The facilitator told him to think about it and decide. He took this issue back to his group for deliberation:

Elijah: She said to put the dry flour in the dry products and the wet products in another bowl, and then its own bowl, the yeast and water, or the yeast and water and sugar. Okay, all that we need to have is the water and the yeast, OR we can have the water, the yeast and the sugar

Jacob: Just the water and the yeast

Elijah: I say the water, yeast and sugar, because the sugar needs the water – no the yeast needs water to wake it up, and it needs to eat the sugar

Jalon: No but then, there’s nothing to trap the air, (raises both of his hands to mimic the air getting away)

David: yeah, there’s nothing to trap it, so the dough is what will trap it

Elijah: Okay, so we put the sugar with the dry products (Jake chimes in)

While the science may not be entirely accurate, we think these learners are focusing on air getting away because of previous KSI experiences with baking soda and baking powder, which have faster reaction times than yeast. They did not want to add the yeast too early, so they decided to add the sugar to the dry products, predicting that the yeast would have it available when everything was mixed together and that the dough would be able to trap the air. This decision, we think, was based on a combination of group questions and experiments during the first Retry Day and during Session 7 where they looked at the elasticity and balloon-like features of flour with water. This was reflected in the group’s presentation of their procedure:

Jacob: We took out baking soda and baking powder, and we added water for the yeast, just because we need the water for the yeast. Then we put the yeast and the water in a different bowl than the dry ingredients and the wet. Then we mixed them all together. It sort of turned out to be a dough, but you couldn’t knead it

Elijah: And we used three bowls because we used one for the yeast, we didn’t want to add that yet, b/c we needed to capture the carbon dioxide, and then we used another bowl for the dry products, and the last one for the wet products.

## Discussion

We designed activities in KSI to try to promote conceptual model building and refinement as well as motivation and engagement. The extent to which we succeeded at both of these things was evident in the things learners said and did.

### Promoting conceptual model building and refinement

Both the Chemistry experiments and the Retry Day activities were shown to be effective for promoting model building and refinement. In the Yeast-Air Balloon experiment, debugging mistakes and redoing the experiment helped the entire KSI group to understand that the temperature of the water is important to the yeast-water-sugar reaction and that the addition of sugar to the system causes the yeast to produce more air. Evidence that some participants learned these two concepts was seen later as learners made alterations to recipes on Retry Day. During Retry Day 1, groups who desired thicker pizza increased the amount of yeast they used, while those seeking flatter pizza decreased it. However, some learners displayed gaps in their understanding of the role of sugar and water in the reaction. For instance, Group 4 doubled the yeast and increased the water, but they did not add any sugar, showing that they did not quite understand that yeast needed to consume sugar in order to rise. The results of their experiment (pizza the same height as the original recipe) and facilitator scaffolding helped them to recognize the role of sugar in the reaction. We did not see them use this knowledge later, so we do not know how well they learned it.

The groups that substituted ingredients in recipes made efforts to transfer what they knew about a leavener to other situations, showing evidence of well-formulated mental models. In making pizza with baking soda and baking powder, Group 2 found that their prediction was correct, reinforcing their conceptual models of how baking soda and baking powder work as leaveners. The group that made cookies with yeast showed in their questions their understanding of the yeast-water-sugar reaction, their ability to apply it in a new situation, and their understanding of where their knowledge was incomplete. A combination of facilitator help and their own reasoning allowed them to add to their models of the yeast-sugar-water reaction and add to their understanding of how to use yeast in recipes, as shown in their presentation. The experience with the dough balls shows significant learning of scientific practice. Learners made comparisons and observations about a variety of characteristics including texture, taste, and smell of their dough. Their comparisons and observations were at least as detailed as those made during facilitated discussions after science experiments.

### Promoting Motivation and Engagement

We found that cooking was generally motivating for the learners. They particularly enjoyed the pizza activity, as demonstrated when each group chose to make pizza for the first Retry Day. Learners were also excited about the “cool” reactions in their science experiments. For the yeast activity, learners took special interest in their balloons after they began to rise, constantly monitoring them for changes and debugging (and redoing) them.

The dough ball activity was particularly engaging for learners who had just completed the task of preparing their pizzas and cleaning up their workstations after a full school day. Typically, at this time (waiting for their dishes to bake), learners’ attention spans wound down, and their energy levels soared. They were ready to play! We often had learners requesting to go outside during this time to play with other learners. However, the interactive affordances of the dough balls allowed learners to freely talk with one another, see the results of what their friends in other groups did, and expend their energy. On the other hand, days where the learners were not cooking (i.e. planning or just science experiment days), were not as successful at sustaining learners’ engagement.

### Concluding Thoughts

We used some of the same examples to illustrate learning and engagement. That, we think, is a key in designing informal learning environments: to design activities that engage *and* promote learning. While we found cooking to be an effective lever into science, motivation and engagement were harder to sustain on days when learners were not cooking. Clearly, learners demonstrated group-construction and worked jointly on refinement of mental models, but it is hard to say to what extent individual understanding changed. We designed the scaffolding in KSI to push learners’ exploration and mental model building in the same manner that parents do for kids in museums. Evidence of children’s learning and engagement suggests that we were at least somewhat successful at that. The literature has shown that parents often have trouble discerning their children’s interpretation of evidence in scientific inquiry due to lack of understanding of their mental models and misconceptions (Gleason & Schauble,

1999). However, the activities, discussions, and learner's motivation in KSI provided a natural and authentic context for learners to articulate their interpretations and make explicit their mental models. In future work, we will be exploring more deeply ways to help children make personal connections to their individual interests and enhance their individual mental models in this engaging collaborative context.

## Endnotes

- (1) All names have been changed.

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