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BRICOLEURS AND PLANNERS ENGAGING IN SCIENTIFIC REASONING: A TALE OF TWO GROUPS IN ONE LEARNING COMMUNITY

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Many learners think of scientific reasoning as something that is done only in the classroom. We aim to develop long-term scientific programs outside of school, helping learners to see and do science in their everyday lives, where the science is not simple and fixed (or pre-packaged). Our challenge is to facilitate the development of a learning community for learners with a variety of interests and learning styles, allowing each to find their own "hook" into science. Our approach is to help learners form a learning community where they participate in science together, taking ownership of their learning and learning science as they pursue their own goals of preparing tasty dishes. In this paper, we present data from our informal learning environment, Kitchen Science Investigators, where middle-school-aged children learn science and scientific reasoning skills through cooking. We are specifically focused on how participants reason scientifically. We look at two groups, who are at opposite ends of two dimensions (interest and planning style) to see how they responded to the scaffolding provided in the environment, how their scientific reasoning skills developed, and the community issues that arose (i.e. group dynamics) among and within the groups. We do this in efforts to draw out issues that arise when designing for a heterogeneous set of learners (along the dimensions of interest and planning style), and to begin thinking about ways to address these issues.

Keywords: Informal learning; scientific reasoning; learning styles and interests.

1. Introduction

Many learners think of scientific reasoning as something that is done only in the classroom. It is easy to understand why. There are many things we know about learning in school, as much work has been done on scientific inquiry and learners' difficulties. The literature tells us, however, that science experimentation and inquiry is often oversimplified in schools, making it hard to relate to the everyday world (Chinn & Malhotra, 2001; Gleason & Schauble, 1999). It gives us some help with understanding what problems children have with school science. For example, we know that children tend to terminate investigations prematurely, forget the purpose of experimentation as they proceed, draw conclusions that are not supported by valid evidence, and fail to recognize what's important about scientific situations (Gleason & Schauble, 1999; Quintana, Eng, Carra, Wu, & Soloway, 1999; Quintana *et al.*, 2004).

What has been suggested instead is to introduce children to the world that authentic scientists live in where (1) the science is derived from real-world problems or issues, (2) the range of variables that can be tested and the outcomes are unknown, and (3) the procedures and their order are not rigidly prescribed (Chinn & Malhotra, 2001; Gleason & Schauble, 1999). Our work follows this suggestion but applies it in an out of school setting. We aim to develop long-term scientific programs outside of school, helping learners to see and do science in their everyday lives, where the science is not simple and fixed (or pre-packaged).

Our approach is to help learners form a learning community where they participate in science together, taking ownership of their learning and learning science as they pursue their own goals. Our domain is cooking and kitchen science. Although all participants in our program are interested in cooking, each participant comes with their own specific interests and goals. Moreover, every learner has a specific planning style that suits him or her best. What works for one learner will not necessarily work for them all. Our challenge is to design the learning environment to facilitate the development of a learning community for learners with a variety of interests and planning styles, allowing each to find their own "hook" into science.

In designing this environment, we ask the following questions: What are the needs of the different types of learners? When do they engage most enthusiastically? How can we encourage these learners to value and build on each other's skills? How can we help different types of learners take on scientific goals?

In this paper, we present data from our informal learning environment, Kitchen Science Investigators, where middle-school-aged children learn science and scientific reasoning skills through cooking. We are specifically focused on participants' scientific reasoning. We look at two groups who are at opposite ends of two dimensions (interest and planning style) to see how they responded to the scaffolding provided in the environment, how their scientific reasoning skills developed, and the community issues that arose (i.e. group dynamics) among and within the groups. We do this in an effort to draw out issues that arise when designing for a heterogeneous set of learners (along the dimensions of interest and planning style) and to begin thinking about ways to address these issues.

We begin by discussing the design of our learning environment, Kitchen Science Investigators, and the methods for the particular implementation presented. Next, we present a case study of two groups followed by a discussion of the issues that arose. Finally, we discuss the implications with respect to supporting heterogeneous groups of learners.

2. Design of KSI

2.1. *Theoretical introduction to design of KSI*

Kitchen Science Investigators (KSI) is an informal learning environment where middle-school youth learn scientific reasoning through exploring the science behind their cooking. We aim to help young learners see the value of scientific reasoning in their everyday lives. Our goal is that in the process, learners will come to see themselves as scientific reasoners and thinkers, particularly those not previously inclined to do so. Problem-based, project-based and design-based approaches (Barron *et al.*, 1998; Blumenfeld *et al.*, 1991; Kolodner *et al.*, 2003; Koschmann, 1996), tell us a lot about designing environments for scientific inquiry in school. In particular, they focus on the need for practice and reflection, and they provide insight as to how to carry this out.

But an after-school environment is not the same as school. In an after-school environment, participants have the choice of whether or not to come. We therefore can't push for reflection in unnatural places, as might be done in school. Instead, we needed to design KSI so that reflection is always supporting participants' personal goals.

The notion of islands of expertise (Crowley & Jacobs, 2002) gives us a snapshot of how this reflection happens successfully in everyday situations. An island of expertise is "a topic in which children happen to become interested and in which they develop relatively deep and rich knowledge" (p. 2). Crowley and Jacobs (2002) tell us that learning in everyday settings happens over many unremarkable moments or events. Whereas at school, learners build understanding via complete explanations, the explanations that parents give in everyday settings are often more simple and incomplete.

Learners are not expected to gain complex, deep understanding in a single moment, but instead the simple, incomplete moments accumulate over time and connections are made across events. In comparing how the expert acquires his/her expertise and how the child acquires his/hers, both processes involve repeated exposure to domain-specific declarative knowledge, repeated practice in interpreting new content, making inferences to connect new knowledge to existing knowledge, and repeated conversations with others who share their interest.

We also took learners' goals into consideration in designing KSI. Nasir (2002) tells us that participation over time in a community of practice has the power to change goals that the learners are forming. As the goals change, so does their focus on learning. For example, in playing basketball, as learners progressed to high school, their basketball goals became more serious, and players thought about going on to play college and professional basketball. To do this, they needed their game statistics to be up to par with college and professional athletes. This required learning and understanding statistics. Then, as players began to compare themselves to college and professional ball players, they began to see themselves as college or professional ball players (or at least capable of being college or professional ball players), using game statistics to motivate their practice and perfection of skills (Nasir, 2002).

In KSI, learners start out with the goal of making tasty dishes. Our aim is to help them experience the role scientific reasoning can play in helping them to get to a tasty dish. In the implementation here, we helped learners experience the importance of texture in the taste of the food they ate, and then they did experiments with different thickeners, looking at how these thickeners affected different dishes. Learners took on the goal of understanding the science behind thickeners and learning how to use them to get the consistency they wanted. Our hypothesis is that in the process of understanding the science, learners will begin to see themselves as people who do scientific reasoning in their everyday lives.

We aim, in KSI, to design a learning environment that facilitates the development of a learning community where learners take responsibility for their own learning and participate in the scientific community in ways specific to who they are. The learning communities literature provides insight for designing this environment. It tells us of the importance of providing learners with opportunities situated in authentic practice with experts that model and help learners to set goals that motivate and lead to learning (Lave & Wenger, 1991; Rogoff, 1994). Designing these environments involves establishing social practices that serve as scaffolds for helping the community reach and extend their goals, learning throughout the process (Lave & Wenger, 1991; Scardamalia, 2002). For example, in Knowledge Building communities, learners are gradually handed the responsibility for their own learning (Scardamalia, 2002). In Hewitt's (2004) example, the teacher allowed learners to directly participate in their own practice, not being afraid to make mistakes, but to articulate their theories and investigate them, the way scientists would, while he watched from afar, able to make immediate corrections when needed.

We are aiming to aid and encourage the formation of a learning community with social practices and opportunities to participate in authentic scientific inquiry via the everyday experiences of cooking. We hope participation in this community will help learners develop identities as scientific reasoners and thinkers by helping them value the use of scientific reasoning for their goal of cooking food that tastes good. We then aim to help them build expertise at scientific reasoning by providing them with opportunities to engage in kitchen science experiments, explore questions that come from those experiments, and use what they have learned to inform their cooking. Our hope is that their goals will become more scientific, and that as they do, their science understanding will become more complex and their conversations will become more nuanced. We hope that given the opportunity to successfully engage in scientific reasoning in this context and to experience its value, KSI participants will begin to see themselves as people who can and do use scientific reasoning in their everyday lives.

2.2. *Design of environment and activities*

As mentioned above, in building islands of expertise, learners need repeated exposure to domain-specific scientific knowledge, practice interpreting new content, and repeated conversations with others who share their interests, and they need to make inferences to connect old knowledge to new knowledge (Crowley & Jacobs, 2002). Learning By Design (Kolodner *et al.*, 2003), a design-based approach to science learning developed in our lab, told us that learners would need exposure to and practice with engaging in the types of conversations that scientists have and the experiments that they run, and it suggested ways to establish a culture of engaging this way in the community. LBD also told us of the importance of whole-group conversations that provide learners public opportunities to engage in discussions where they are asking scientific questions, designing experiments, discussing results, and incorporating what they are learning with what they already know. We also knew from LBD's design iterations that learners needed to be focusing on designing a working product, in our case, recipes (Kolodner *et al.*, 2003).

Building on LBD's idea of developing a culture of collaboration and rigorous scientific reasoning early on, the first part of KSI is designed to establish social practices necessary for the formation of a learning community. KSI begins with learners coming together as a whole group to figure out how to answer a cooking or baking question (e.g. I am trying to make brownies and I like mine cakey instead of gooey. What ingredients can I use to get more cakey brownies?). This usually involves a group experiment where the community breaks into small groups that each make the same recipe, varying one ingredient or procedure to learn the science behind that ingredient or procedure (e.g. making brownies with different amounts of eggs). Cooking activities are usually supplemented with science experiments that draw out the science behind what is going on in the dish (Clegg, Gardner, Williams, & Kolodner, 2006). These sessions serve three purposes: (1) to build foundations in science content (2) to build foundations in scientific reasoning skills and (3) to give participants the experience of learning together. After several of these structured sessions, learners progress to Choice Days where they choose to change a recipe or further explore a phenomenon they've been introduced to. As they make progress, we encourage a broader range of choices. Whatever the day's activities, learners begin and end with a whole-group discussion where they design experiments, discuss results, and draw conclusions.

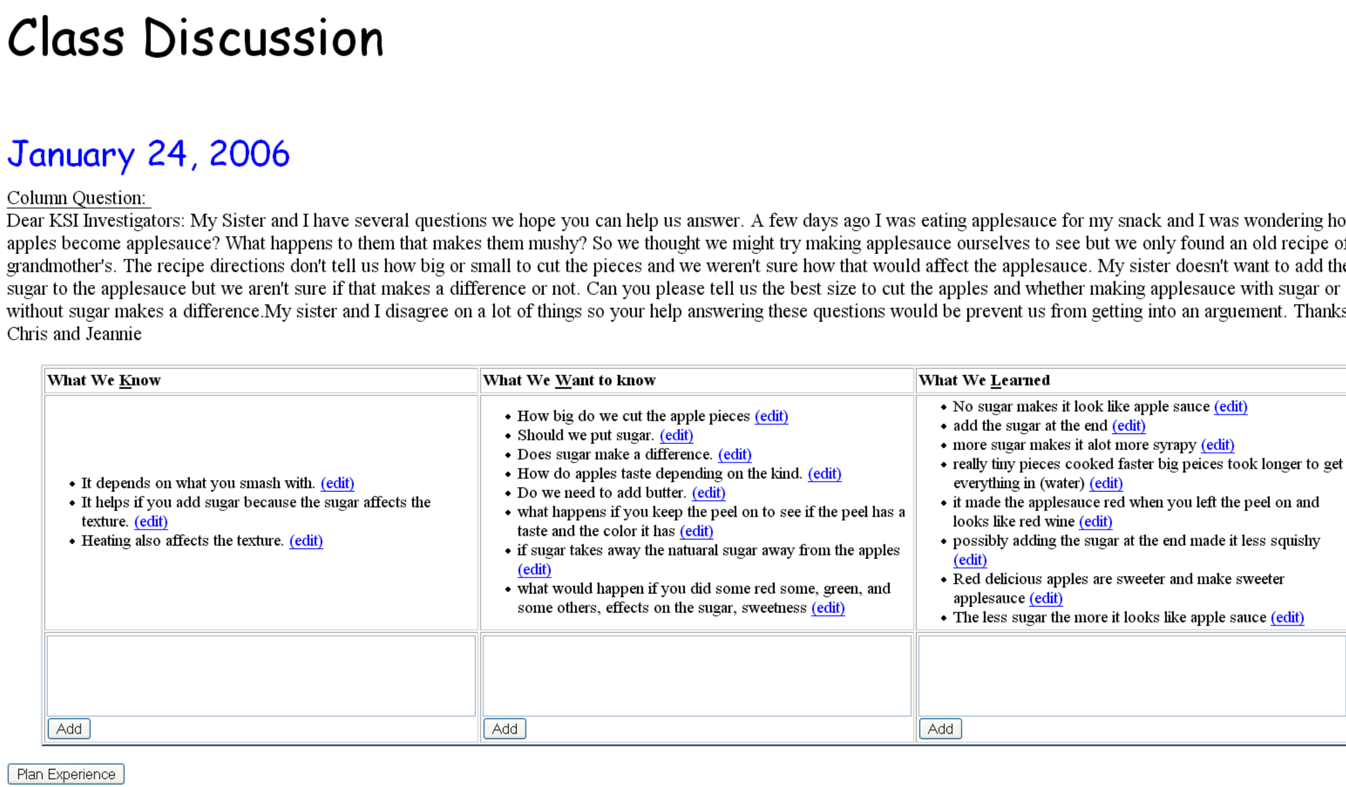
For the particular implementation reported here, Kitchen Science Investigators focused on thickeners and how they worked. In the first session of the program, learners engaged in Messing About activities, where they tasted various foods pureed and in their regular form. They used blindfolds and nose plugs to experience the texture and taste of the foods without the sense of smell or knowing what it was. They did this so that they could begin exploring their food in more descriptive ways and to understand the importance of texture in foods. This also provided learners, already acquainted through school, with an opportunity to get to know each other in this context (Nasir, 2002). During structured sessions, learners all made the same recipe, varying one ingredient to see the effects of that ingredient. In Session 2, learners began by making apple sauce, varying the amount of sugar used during cooking. The purpose of this activity was to see how osmosis causes the apples to break down to become apple sauce (and to see how sugar is a hindrance to this). Session 3 was a Choice Day where learners were allowed to change the apple sauce recipe in a way that they desired to explore a different aspect of the recipe (other than the sugar). They used different types of apples and varied procedures to reach their desired results. In Session 4, another Structured Day, learners explored the use of flour to make gravy, as well as different cooking techniques for chicken, making chicken and gravy dishes. Different starches (e.g. cornstarch, brown rice flour, tapioca, and tapioca flour) were explored in Session 5 to make pudding. In Session 6, learners explored eggs as thickeners by making chocolate pie and quiche. The last structured session was Session 7, where learners explored rice as a thickener and made rice pilaf. Sessions 8 through 10 were Choice Days where learners could choose from among recipes that used thickeners (there was a selection provided) or recipes that they had made in the previous weeks and revise them to their liking. They made and revised these recipes based on the science they had learned about particular thickeners.

2.3. *Facilitating learning: Design of software*

Scaffolding in our environment comes from a variety of sources: leaders, other learners, and software. Adult leaders facilitate group activities, answering questions, prompting learners to think about their experiments and the science behind their cooking. They also lead whole group conversations, guiding the discussion to help learners think about relevant issues as they design experiments, discuss results, and draw conclusions. Learners in KSI scaffold one another in a similar manner. Based on modeling from leaders, they also prompt each other to think about the science behind their dishes, the experiments they are planning, and the reasoning behind the design of their experiments.

We designed the software to prompt scientific reasoning. During whole-group conversations, the software is displayed on a large screen, with a scientific question for the day (called the Column Question). One learner records all the questions arising from the column question and from learners. The large group uses a chart with columns for (1) what they want to know, (2) what they want to learn, and (3) what they have learned (a KWL chart, see Figure 1) to discuss what they already know about the questions at hand, and to design group experiments that will help them answer the questions remaining. They run their experiments in small groups and then come back to discuss their results, using the software to refer them back to their questions and to input their conclusions.

During small-group activities, the software encourages learners to stop and reflect during the busy activity of cooking (Gardner & Kolodner, in press). The



Class Discussion

January 24, 2006

Column Question:
Dear KSI Investigators: My Sister and I have several questions we hope you can help us answer. A few days ago I was eating applesauce for my snack and I was wondering how do apples become applesauce? What happens to them that makes them mushy? So we thought we might try making applesauce ourselves to see but we only found an old recipe of my grandmother's. The recipe directions don't tell us how big or small to cut the pieces and we weren't sure how that would affect the applesauce. My sister doesn't want to add the sugar to the applesauce but we aren't sure if that makes a difference or not. Can you please tell us the best size to cut the apples and whether making applesauce with sugar or without sugar makes a difference.My sister and I disagree on a lot of things so your help answering these questions would be prevent us from getting into an arguement. Thanks, Chris and Jeannie

What We Know	What We Want to know	What We Learned
• It depends on what you smash with. (edit) • It helps if you add sugar because the sugar affects the texture. (edit) • Heating also affects the texture. (edit)	• How big do we cut the apple pieces (edit) • Should we put sugar. (edit) • Does sugar make a difference. (edit) • How do apples taste depending on the kind. (edit) • Do we need to add butter. (edit) • what happens if you keep the peel on to see if the peel has a taste and the color it has (edit) • if sugar takes away the natuaral sugar away from the apples (edit) • what would happen if you did some red some, green, and some others, effects on the sugar, sweetness (edit)	• No sugar makes it look like apple sauce (edit) • add the sugar at the end (edit) • more sugar makes it alot more syrapy (edit) • really tiny pieces cooked faster big peices took longer to get everything in (water) (edit) • it made the applesauce red when you left the peel on and looks like red wine (edit) • possibly adding the sugar at the end made it less squishy (edit) • Red delicious apples are sweeter and make sweeter applesauce (edit) • The less sugar the more it looks like apple sauce (edit)
Add	Add	Add

Plan Experience

Figure 1. A snapshot of the KSI Class discussion tool during Session 2. Column Question is pictured above the KWL chart as learners discuss as a whole group.

recipe is displayed step-by-step with space for group members to write observations, ideas, thoughts, and questions (see Figure 2). Participants are also equipped with cameras at their workstations where they can take pictures of their dishes. After making their recipe, they can upload the pictures into the software — associating each picture with the particular step it goes with and writing notes about each picture. They can then see the recipe displayed with their pictures and observations at each step. These features were designed to help learners recognize the effects of ingredients and procedures as well as for documenting what they saw so they could refer back to it later. During Choice Days, each group created a page for observations using software prompts to help them enter their recipe so it could be displayed. To prompt learners to make observations and compare results across groups (or simply share results), a display page with each groups' current observations is displayed on the wall during cooking activities.

2.4. *Addressing multiple learning styles and interests*

Levi-Strauss (1966 [1962]) distinguishes two distinct ways of investigating the world, that of the bricoleur and that of the scientist. A bricoleur investigates by manipulating objects. A scientist or planner prefers a more rule-based and abstract style — preferring to remain further from objects focusing on the object itself and it's actions, as opposed to the object's component parts or mechanisms. Levi-Strauss asserts that they both do science, but they come out with different products. Turkle and Papert (1991) take this a step further arguing that bricoleurs and planners are at two ends of a spectrum, that most people do both, though they might prefer one over the other, and that both ways of thinking should be valued.

So what does this mean for Kitchen Science Investigators? In terms of cooking, the bricoleur cook is one who lets the product emerge as a function of how things taste, look, or feel. A scientific cook follows procedures closely throughout a recipe, making suggestions for future preparation of the dish only after the final product has been tasted and analyzed. We knew that our learners were coming first and foremost for the cooking. That told us we needed to use the cooking as a lever into the science, letting all science stem from the particular issues they were dealing with in their dishes. However, when designing KSI and its software we did not yet know the extent to which our learners would be bricoleurs or planners and what their differing scaffolding needs would be. Nor could we have anticipated the differential impact scaffolding could have on different types of planners and how that would effect establishing a learning community where all types of scientific reasoning are valued. We want to make sure that both planners and bricoleurs feel welcome and remain engaged in KSI activities.

KSI members also differ on another dimension — interest. Some come to KSI very interested in the science behind cooking. Others come for the cooking and are less interested in the science. We want to make sure that participants with more and less interest in formal science feel at home in KSI and remain engaged in its activities.

Figure 2. A snapshot of one group, the Jaguars', KSI software during cooking activity in Session 2. Learners add observations in the textbox and they appear in blue underneath the step number. The step instructions are above the observations toward the right.

Learners work in small self-selected groups in KSI, and during the KSI implementation we found that two groups participated at the extremes of both continua. The Jaguars, our planners, were particularly interested in the science. The Carb Junkies, on the other hand, were bricoleur learners interested mainly in cooking. Each group consisted of four individuals and for the most part, interests of group members seemed to be consistent with one another and each group exhibited a recognizable group planning style. Analyses of the experiences of these two groups has given us insight as to how we can better design our environment to meet the needs of learners with a variety of interests and learning styles. It also sheds light on how we can better establish social practices that help learners value all types of scientific reasoning.

3. Methods

In this study, we present data from a 10-week implementation of KSI held in Spring 2006 at a local private school. KSI, in this implementation, was a weekly after-school science club program. This was the second 10-week session we had done at this school. The first session, held in Spring 2005, was exactly a year prior to the one reported here. During Spring 2005, we had 16 participants (8 male, 8 female). For this implementation, we had 17 participants, 11 of whom were returning from the previous year. We had 5 females and 11 males. KSI was held once a week for $1\frac{1}{2}$ hours after school. There were three facilitators who led whole-group conversations and helped small groups as needed during activities. All days were video recorded and a fourth researcher was present on some weeks, taking field notes. Group interviews were conducted at the end of the program to find out about learners' perception of the software and activities in KSI.

In analyzing the data, videos were watched and semi-transcribed (we transcribed conversations that involved anything other than playful banter). We also looked at the corresponding entries learners made to the software on relevant days. Based on our foundational literature, we were looking for the building of identity and tracking development of islands of expertise (Crowley & Jacobs, 2002). The literature suggested that in looking for these things, we pay close attention to the types of conversations learners were having (looking to see if they were starting to contain elements and structure of scholarly discourse — in our case, authentic scientific reasoning), their opportunistic noticing (and the agency they were taking on for this), their goals, their capabilities, and their practice styles.

We found that the literature we used to design KSI gave us a good idea of *where* to look for scientific reasoning skills, but it did not tell us *what* to look for. We therefore used Chinn and Malhotra's (Chinn & Malhotra, 2001) framework for authentic scientific reasoning to determine if we were seeing scientific reasoning and if so, what kind of scientific reasoning we were seeing and how it was progressing. Chinn and Malhotra (2001) use a model-as-data method for comparing the way authentic scientists conduct experiments to the way that science is typically done in school (which they call 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, 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 (they look at this as a continuum).

We examined the experiences of the *Carb Junkies* and the *Jaguars* in detail. We chose these two groups because they were at two complete extremes in terms of interest and learning style. While the *Carb Junkies* tended to participate as extreme bricoleurs, the *Jaguars* participated as planners interested in cooking and science. We analyzed data for these groups from Sessions 2, 5, and either session 9 or 10 (according to the data we had available for that group), one session in the beginning of the program, one in the middle, and one the end, spanning structured and choice sessions. There was some change in group members, as well as some absences from one day to another, but overall, these two groups remained the same. Table 1 shows which individuals were present in each group on each day.

We used Chinn and Malhotra's (2001) framework to go through the video data (and resulting semi-transcriptions), finding places where scientific reasoning was being displayed. We then organized these temporally according to the type of reasoning displayed, analyzing each in terms of it's authenticity, simplicity, or lack of the reasoning skill (e.g. not making observations at all). This analysis allowed us to see how the two groups' scientific reasoning skills developed, what helped, and what was needed. In this paper, we focus on the reasoning skills that were most emphasized in this implementation of KSI (making observations, designing experiments, and finding flaws).

Now, meet the groups and hear their stories. Then we will look at the scientific reasoning skills each group displayed, the community issues they faced, and the ways our software helped or hindered that development. We will then discuss the implications of designing a learning environment that allows various types of learners a chance to "hook" into the scientific reasoning in their everyday lives.

Table 1. The days observed and the individuals in each team present on those days (first-year KSI learners are *italicized*).

Group members on:	Jaguars	Carb junkies
Session 2: Applesauce	Brian, Jordan, Nicholas, *Orlando*	*Austin*, Donnie, Adrian (Caleb was sick)
Session 5: Pudding	Brian, Nicholas	*Austin*, Adrian, Donnie, Caleb (last 1/2 of day)
Choice Day	Session 9: Chicken and Gravy Brian, Jordan	Session 10: Strawberry Cobbler *Austin*, Donnie, Caleb (Adrian absent)

4. Participants: The Carb Junkies and the Jaguars[1]

In light of the tendencies, interests, and styles that we observed, we place the Carb Junkies on the bricoleur end of Turkle and Papert's learning style spectrum. The Carb Junkies were tinkerers, changing recipes as they saw fit, keeping track of taste and texture, and making changes accordingly. Also, in light of their statements of why they chose to come to KSI, as well as our observations of their reactions to our scientific scaffolding (i.e. participating in discussions, etc), we place the Carb Junkies on the "cooking" side of the interest spectrum.

The Jaguars, on the other hand, treated recipes as directives, following them closely when given recipes to follow and planning procedures carefully when designing their own. They were also careful observers. This group acted as planners and their interest was in the science behind their cooking.

During group interviews, two Carb Junkie group members (Caleb and Donnie) described their view of the two groups as follows:

> Caleb: Mmmm hmmm. Our group wasn't the best group there was.
> Tammy[2]: What do you mean by best group? . . .
> . . .
> Caleb: The most on task
> Donnie: We were!
> Caleb: Or like -
> Donnie: I thought Jordan's group was the most on task (*Jordan was a Jaguar group member*)
> Caleb: - into it to find the answer! We're like into it to have fun.
> (Carb Junkies Group Interview, Spring 2006)

5. Results

We use Chinn and Malhotra's (2001) scientific reasoning framework to look at the progress learners made in terms of their scientific reasoning skills. Here we discuss skills learners displayed in three parts of the framework: making observations, designing experiments (in particular, selecting and controlling variables and planning procedures), and finding flaws. We begin by explaining each category and then we present each group's development of that particular reasoning skill.

5.1. *Making observations*

Chinn and Malhotra's (2001) framework for the progression from simple scientific reasoning to more authentic scientific reasoning states that scientists make observations to prevent or check for perceptual biases, whereas more novice scientific reasoners tend to perform few checks and focus primarily on measurements. In KSI, our goal in terms of learners making observations was to help them to move

[1]Groups were self-selected and all group names and individual names have been changed.
[2]Tammy is short for Tamara (the first author of this paper), also a facilitator in KSI.

from opinion-based descriptions (e.g. the apple sauce tastes very good) towards descriptive observations (e.g. it tastes sweet). We prompted them to take pictures at different points in their experiments to help them monitor changes and to allow them the opportunity to return to their data and re-describe it more objectively. The pictures also allowed peers to help them develop better descriptive capabilities, as they allow others to see and comment on discrepancies between participant's descriptions and the raw data. It was interesting to note how both groups progressed in this area and the help they needed. In excerpts that follow, notice the points at which each group took initiative in making observations, the focus of the different groups' observations, the tools used to make those observations, and the help each group needed.

5.1.1. *Jaguars*

In Session 2, as learners were making apple sauce, several science tools were placed in the environment so that learners could make different types of observations. The Jaguars immediately grabbed these tools and began using them to make observations. They used the food scale to take measurements of the apple's weight. They also went to the microscope in the corner of the room to observe their apples at a closer level of detail. They talked about the weight of their apples and observed the texture of their dish as they were cooking.

> Jordan: [comes back with apple piece] It wasn't really zero, but it was less than an ounce [reporting results from measurements of an apple wedge on the food scale]
> Orlando: It's getting more mushy, and a little light. It's starting to get more mushy, so... And uh, the apples are mushy [someone is typing this in the software]
> (Day 2, Spring 2006)

The Jaguars talked about what they were seeing and they reported these results in the software. At each step, they recorded in the software the progress of their dish, its weight at that step, and what it looked like under the microscope (except for step 3). The following is an example of this from Step 1:

> It is starting to sizzle. it is also getting squishy early.
> The apples are starting to spread apart under the microscope. The apple weighs absolutely nothing.
>
> (Software Observation for Step 1: Day 2, Spring 2006)

There was only one microscope, and those using it also had a chance to see other groups' apples under the microscope and see what they were doing. This sometimes led to comparisons. For example, during Session 2, the Jaguars ran into a problem: their apples were not "melting down." They began to look at what other groups were doing, monitoring the changes they saw in other groups' apples and comparing those changes to their own. They looked at what the adjacent group did (they cut their apples smaller and used higher heat) to figure out what they should do. One member of the group, Jordan, was careful to describe what was happening to another groups' apples as precisely as he could. As a group, they used their observations of the differences between their dishes to make decisions about what they should do to get their apple sauce to the desired consistency. They eventually decided they needed to turn their heat up higher to get their apples to boil like the other groups'.

During Session 5, as the groups made pudding, the microscope and food scales were not available, but the Jaguars continued to display their planning style, making observations about other groups' dishes in comparison to their own. They used these observations to reason about their next steps. However, we had to remind them more often to record observations during this session than we did during Session 2.

In Session 9, the Jaguars decided to perfect the chicken and gravy recipe they made in Session 4. However, they were not able to find the recipe for the gravy in the software. So they relied on a facilitator (and partly on their own memory) for the recipe. Without scaffolding to help them, they were not recording specific amounts as they went, even though the facilitator talked to them about specific amounts, and they acknowledged this when writing about their experience.

5.1.2. *The carb junkies*

In Session 2, the bricoleur group, the Carb Junkies, did very little formal observation. Although facilitators and the group next to them prompted them to make observations, they often ignored this prompting, changing the subject, or walking away. The pictures they took were primarily of one another; occasionally they included the dish in these social pictures. At one point in this activity, they are prompted to make observations (beyond opinion). When their apples were not "mushing," Donnie looked over at the adjacent groups' apple sauce (the Alligators) and saw that their apples were getting softer a lot more quickly than their own. This prompted them to discuss the differences in what the Alligators did (no sugar), talk about the smell, and then talk about a possible mistake the Carb Junkies made (too much lemon juice).

In Session 5, the Carb Junkies responded more to prompting when we prompted them to observe. However, they needed help figuring out what to observe and how to articulate what they were observing. Facilitators had to ask specific questions, and they often came out as requirements for what it means to make an observation:

> Tammy: ... So, keep writing, I want to hear some things about the texture though
> Austin: Okay, next thing, next thing! Do not - Look at it, it's really thick, it's really thick [moves his plastic spoon through the pudding, speaks fast]
> ...

> Tammy: It is thick [to Austin]. But look, is it – [Austin begins to laugh at Evan's comment] What is the [*inaudible*] like though Austin?
> Austin: Grainy
> Tammy: Write up what the [*inaudible*] like [to Adrian and Austin, Austin goes to computer, Adrian stops at pot and stirs and smells]. Tell us some things about the smell, and the texture . . .
> Adrian: Oh! It smells terrible.
> Austin: [going over to computer] okay [he smells the pot]. No it doesn't!
> Tammy: And write what it smells like!
> (Day 5, Spring 2006)

They entered the following into the software:

> tapioca makes pudding gritty and tastes kinda weird
> (Software, Day 5, Spring 2006)

As they are making their pudding, Austin is prompted (by recipe instructions) to use a metal spoon to test for thickness. He continues to use this test to monitor the pudding on his own (although not articulating the results of these tests, or inferences he made from them).

In Session 10, the Carb Junkies chose to make strawberry cobbler. They made a strawberry and chocolate filling sauce for their cobbler by mixing the juice from strawberries with chocolate, sugar, and thickeners. Because this was a Carb Junkie created recipe, it was not in the software. The group was given a textbox on their own web page (of the software) to write about their experience. By Session 10, they had attempted to make apple cobbler (Session 8) as well as strawberry cobbler (Session 9). Both cobblers they made were too runny, so they were trying to perfect the texture and taste of their cobbler in Session 10. Austin seemed to be creating his own tests (using a whisk to monitor thickness); this time he talked about the results of the test (e.g. it's getting thick). He closely monitored the changes in their dish. Although he did not record any of these changes in the software, he verbally talked about them. Checking the whisk each time someone walked by, he gave continual reports to facilitators of the sauce's thickness (e.g. "it's too thick" or "it's too thin"). He also began to give descriptions of their sauce (e.g. "This is chocolate. This is like pure chocolate," describing the sauces look and texture).

5.1.3. *Comparison*

Several differences stand out in the way in which each group progressed in making observations. While the bricoleurs tended to make observations only of their own dishes, the planners observed the entire experiment, noting the specific differences between their dish and other variations. Planners used the microscope and food scale to make observations, whereas our bricoleurs relied on their senses and cooking utensils. Planners were more engaged in observations during structured days while bricoleurs did not become motivated to make observations until Choice Days. The planners did not need as much reminding to make observations during structured days, while the bricoleurs were not motivated to make any observations until they ran into problems with their own dish and had a need to solve their own problem.

5.2. *Designing experiments*

Chinn and Malhotra's (2001) framework addresses four aspects of designing experiments — selecting variables, controlling variables, planning measures, and planning procedures. We saw our groups selecting and controlling variables and planning procedures.

5.2.1. *Selecting variables*

In simple experiments, students usually have variables selected for them whereas scientists "select and invent variables to investigate." (Chinn & Malhotra, 2001) In KSI, we aimed to give learners more agency in this process by allowing them to discuss as a group and decide what variables they would investigate (during Structured Days). Facilitators provided help with this. Ingredient and equipment resources available helped the decision process by constraining their options. Also, the Column Question and KWL chart helped learners to discuss their options by allowing them to outline possible variables to investigate.

5.2.2. *Controlling variables*

Simple experiments typically involve a single control condition and students are told what to control for and how to set up a control. Scientists, on the other hand, often employ multiple controls and sometimes find it difficult to determine what to control and how to control for certain things. In KSI, we designed the Structured Days to provide learners with opportunities to design simple controlled experiments themselves (each group making the same recipe, varying only one ingredient or procedure). However, as they followed recipes, learners often ran into ambiguities in the recipe instructions. Facilitators prompted learners to recognize these ambiguities as variables that either needed to be controlled or could not be controlled (e.g. the size of apple slices was not specified, and learners subsequently cut their apples in different sizes and later recognized this as an uncontrolled variable in their across-class experiment).

5.2.3. *Planning procedures*

While simple experiments typically involve following a set of instructions, scientists often "invent complex procedures to address questions of interest." (Chinn &

Malhotra, 2001) They also devise analog models to address research questions (e.g. investigating cancer genes in rats to learn more about humans). While we do not address the issue of analog models in KSI, participants sometimes invent their own procedures to measure something or achieve a desired result in their dishes.

In the excerpts that follow, notice we were able to help the Jaguars, our planner group, think about selecting and controlling variables. The Carb Junkies, our bricoleur group, were able to use scientific reasoning to plan creative procedures.

5.3. *Jaguars*

During the whole-group conversation at the beginning of Session 2, the KSIers reviewed the questions raised. They started by selecting a variable to investigate (based on the questions raised), discussing whether they wanted to find out about the effects of butter, sugar, or apple size. Orlando wanted to investigate the effects of butter on apple sauce, while Jordan preferred to look at the effects of the size of the apples on apple sauce (cutting theirs in quarters). Most participants wanted to explore the effects of sugar on apple sauce texture. Following the majority choice, each small group made apple sauce with a different amount of sugar.

As the Jaguars worked, they followed instructions closely and discussed the effects of not only the variable they were investigating (sugar), but also the variables they were trying to keep constant. When a recipe had ambiguities they discussed the possible ways of interpreting the ambiguity and its possible effects (e.g. the size that they should cut the apples was not specified, Brian guessed that smaller apple pieces would make it easier for the apples to dissolve, while Orlando thought it would just be "more pieces of the same thing, but smaller"). When they saw another group doing something differently than they were, they also discussed the importance of controlling variables across groups and what the effects of not controlling that variable might be (e.g. the effects of using a higher heat setting on their apple sauce texture).

They also had conversations with other groups where they connected their variable of interest with the results they were seeing. Once they observed the adjacent group's apple sauce and looked at the amount of sugar they were using and also noticed other differences in how they were making their apple sauce (e.g. apple size, heat) and discussed these differences. However, they often discussed other variables (e.g. apple size) being the cause for their results before they began to think about the variable of interest (sugar) being the cause.

In Session 5, when they found lumps in their pudding, the Jaguars realized (based on a conversation with a facilitator and their own observations) that the amount of stirring is an important variable to control when making puddings. They shared these results with the group next to them as well as other facilitators when they came by.

During Session 9, they decided to perfect the chicken and gravy recipe. They were intending to make the same recipe they had made on Session 4. Here, for some reason, they needed to be reminded to manage variables and plan procedures well (e.g. as they were adding flour to the gravy, the facilitator reminded them several times to record the amount of flour they were adding, but they never did).

5.3.1. *Carb junkies*

During Session 2, the Carb Junkies started out quite uninterested in formal experimentation. Both facilitators and their peers prompted them to select and control variables, but they usually ignored the prompting by walking away or not responding. On the other hand, they were quite interested in and creative about noticing problems in their recipe and solving them. For example, when their apple sauce was too runny, instead of following the recipe, one member (Austin) developed a solution to smash the apples and drain the excess water out. This in turn required creating "mashers" with spoons and containers.

In Session 5 the Carb Junkies wanted to add sugar to the recipe, but facilitators did not permit this, requiring them to follow the recipe (although they added it anyway when facilitators were not around). Their motivation to add sugar was based on their reputation for adding sugar to their recipes. Although the group followed the facilitator's request to follow the recipe, they made sarcastic comments about having to do so. They were not particularly concerned about precision until they received negative reactions from their peers to their pudding. During the ending whole group conversation, this prompted them to blame one another for imprecision in following the recipe which they thought was one cause of their results. Austin also blamed the "horrible," "way too thick" consistency of the pudding on the texture properties of tapioca ("Its tapioca!!!", "... Tapioca is like little balls of stuff that don't feel right").

In Session 10, the Carb Junkies chose to work on perfecting fruit cobblers for the third week in a row. They were trying to get it thick enough so that when they cut it, "it just held in place." Although in previous tries, they had gotten it thicker, it was not reaching this goal yet. Therefore, they created extra measures to get their desired thickness. They "boiled the strawberries to get the juices out," they "strained the juices out" (using a pan and its lid as the strainer). They then added flour, sugar, and chocolate bars, which "made it thicker" as well. In their presentations, the Carb Junkies describe it this way:

> *Caleb*: Yeah, we uh, first, Austin ah, heated up the strawberries so they were unfrozen, and then we put them in a strainer to get the juice out and we like set the strawberries aside, with the pie in the thing and —
> *Austin*: We put the crust in the pan, then we boiled the strawberries to get more juices out. So after we put the strawberry juices in the strainer, we put them in a big saucepan and we put three, we put six, one by one bars of chocolate, then the candy melted down and

> it made it thick. Then we put the six cups of sugar and one third cup of flour in. Then it got kind of creamy and then it started getting thin, so we ...
> *Austin's mom*: I can't hear you
> *Austin*: We took a really long time trying to put together a pie-crust
> *Caleb*: Yeah because the dough ran out. So we had to go around asking for scraps
> (Day 10, Spring 2006)

5.3.2. *Comparison*

During Structured Days, the planners usually took on the goal of answering the Column Questions and running group experiments. They spent much time designing experiments, controlling and selecting variables. On the Choice Days, however, they needed a lot of help with planning procedures[3]. The bricoleurs, on the other hand, never took on the goal of answering the Column Question and running experiments with the rest of the community. As a result, we saw them doing little selecting and controlling variables. They were motivated instead to creatively "invent" procedures and tools to make their dishes. In the end, we saw that led to them developing an ability to use scientific reasoning to plan procedures, as they showed on Day 10.

5.4. *Finding flaws*

Chinn and Malhotra's (2001) framework states that scientists are often concerned with flaws in methodology and interpretation in both their own experiments and those of others. In KSI, we aim for learners to look for flaws in their procedures (following the recipe) and in those of other groups. In the described results, notice the context in which each group was concerned about precision and the differences in what they were being precise about.

5.4.1. *The Jaguars*

During Session 2, the Jaguars found flaws, not just in their cooking, but in their scientific measurements. Jordan noticed that the food scale they were using was not set to zero. Not only did the group account for this in their measurement (subtracting the difference of the offset), but Jordan proceeded to fix the scale so that it would be accurate.

> *Jordan:* [with the food scale] Did you weigh anything with this? [to Nicholas] This is so not good [Brian looks on] It's zeroed out at about three ounces [Brian and Nicholas look on]

[3]While the results could have been due to the lack of a recipe on Day 9, we also observed similar results on Day 8, when groups had recipes. They were more precise in their measurements on Day 8, but the scientific reasoning displayed was comparable to Day 9.

> *Brian:* Can it go up to zero?
> *Jordan:* Yes it can ... [he twists the plate part of the scale, as if to make it go up]
> *Jordan:* Give me an apple back, I got the scale working
> *Brian:* Jordan, we just did this.
> (Day 2, Spring 2006)

During Session 5, the Jaguars continued to be concerned about precision, this time while making their pudding, particularly after they found lumps in their first batch. They started the recipe over, careful not to make the same mistake. When adding ingredients, they were conscious of any imprecision. If they were not precise in their measurements or procedure, they wanted to start over, making predictions about what effects the mistake would have.

During Session 9, a Choice Day, their concern for precision waned. As they were cooking, the facilitator helped them to take measures to monitor how much flour they were adding. As time went on, they lost track of these amounts and as they made sporadic changes to the recipe, they stopped monitoring amounts they were adding. In the end, they acknowledged this when writing about their recipe.

5.4.2. *The carb junkies*

In Session 2, the Alligators (the group adjacent to the Carb Junkies) came over to suggest possible causes of the Carb Junkies results, but the Carb Junkies did not participate in discussion about the causes. During Session 5, the pudding day, although the Carb Junkies followed recipe instructions, they often made mistakes in measurements (e.g. they added too much salt), and they decided to add more sugar than the recipe called for. They never saw adding too much sugar as a flaw, although other groups chastised them for doing so.

By Session 10, one member of the group, Austin, was starting to be concerned with how to get results they wanted. Others in his group still seemed not to care about procedure. One particular group member, Donnie, chose not to carry out certain tasks because of their "complexity."

> *Austin:* Drain the strawberries [as Donnie's pouring]. Watch out, it's gonna come out slowly... It's not hot
> *Donnie:* Alright, but Austin we can't do that
> *Austin:* Yes we can
> *Donnie:* Austin how are you gonna do that? It's too complex, just do it like the old way [or add it all in???]
> *Austin:* No, because, we need to um, last time it got all runny... We need to drain all this stuff out of that. [pause] Where's Adrian?
> (Day 10, Spring 2006)

5.4.3. *Comparison*

In summary, we see that the Jaguars were concerned about precision in following the recipe, particularly during structured days. They also thought about the effects of imprecision or inaccuracy. The Carb Junkies were not concerned about precision until they ran into problems that mattered to them. They were never precise in following the recipe. Instead they were precise in following their own creatively invented procedures.

6. Discussion

The results presented tell us several things about the needs of different types of learners and when they engage most enthusiastically and suggest ways of encouraging learners to value and build on each other's skills and helping different types of learners take on scientific goals.

6.1. *Scientific "hot spots": When do participants engage most enthusiastically?*

In looking at the data, we noticed that there were times when groups or individuals were especially motivated to think scientifically and where we see them taking initiative in their scientific thinking. We call these moments scientific "hot spots" and we saw them with both groups, but at different times. The planner group, the Jaguars' hot spots occurred during Structured Days, when the groups were all working on variations of the same recipe to answer a question. During these activities, the Jaguars showed great enthusiasm for thinking about selecting and controlling variables, as well as finding flaws in their methodology and measurements. The bricoleur group (the Carb Junkies), on the other hand, experienced these moments when they were able to design their own recipes. During these times, they (at least Austin) became concerned about precision, and they designed tests and tools to monitor and obtain their desired results. At these times, their goals were more scientific. While the Jaguars seemed to be more intrinsically motivated by answering questions, the Carb Junkies were more motivated by solving small problems in the context of getting to a personally meaningful product.

6.2. *Science tools and needs: What are the needs of different types of learners?*

Because the groups had different hot spots, they also had differing scaffolding needs. The scientific group used scientific tools during planned experiments to probe deeper (e.g. food scales and microscopes). The bricoleur cook altered and engineered cooking tools to reach his goals (e.g. making a strainer to drain juice out of strawberries, using a whisk to measure thickness). The results of our analysis give us some ideas as to the software that might be provided to planners and bricioleurs to scaffold their scientific reasoning.

During structured days, the scientific planners were more inclined to think scientifically. They were especially motivated to compare other groups' variations with their own. Scientific tools placed in the environment scaffolded their observations. These tools (e.g., the microscope and food scale) helped them to look at their dishes at different levels of detail and to make quantitative observations. During these days, the scientific planners needed support for documenting their quantitative observations and ways of later using them to draw and support their conclusions.

During Choice Days, without physical access to variations of other groups, the scientific planners needed more prompting to make observations. The lack of structure during Choice Days caused the more scientific group to revert away from the scientific reasoning they were previously doing. They needed optional planning tools to help them design their recipes scientifically, as well as more frequent whole-group discussions where they could refine their plans by being questioned by other groups and recieving help from facilitators.

The bricoleur group on the other hand, was motivated by the goal of perfecting their dishes. During structured days, facilitators' scaffolding for making observations helped the group to take more descriptive observations. However, the science and scientific reasoning became more useful to them during choice days as they encountered problems with their dishes. In fixing these problems, the bricoleur group needed to explicitly see the role of science in their food. They also needed scaffolding for selecting and controlling variables in this context (e.g. figuring out what variable(s) was causing the problems in their dish). Prompts for relevant content information at opportune times would also help bricoleur cooks to explore the science in a personally meaningful way. Because the bricoleur's experiences were very different from the scientific planners', they also need more ways to document their experiences than the traditional step-and-observation manner we provided in the software. The bricoleur group's explanation of their procedure to their parents and in the software also suggests that they need prompts during activities for short articulations that will help them to recall specifics of their experiences when they write about them later.

In summary, we make several suggestions for helping both types of learners engage in scientific reasoning in and out of their hot spots.

(1) Facilitators need to help learners recognize and address specific areas of scientific reasoning where they need help.
(2) Tools need to be placed in the environment at the right times to spark and enhance learners' scientific explanations. Software can help address this issue by providing learners with relevant scientific content information at appropriate times and prompting for learners to articulate and seek relevant information during experiments.
(3) Learners need articulation tools to prompt and help them make quantitative observations, write specific scientific details about their experiences, and make

plans for choice days. Software needs to facilitate and encourage these types of articulation.

6.3. *Community building: how can we encourage learners to value and build on each other's skills and knowledge?*

The community needs to support and encourage all types of scientific reasoning. There was a split in the goals of members of the community that was reflected in the development of different values for different learners. But the skills displayed and interactions show that there could be a way to get them to better appreciate each other's expertise. For example, the Jaguars could have used their experience with selecting and controlling variables to help the Carb Junkies narrow down the causes for their runny cobbler. Likewise, the Carb Junkies could have helped the Jaguars design a procedure to get the lumps out of their gravy. The Carb Junkies were able to develop scientific goals as they began to creatively design recipes in a way that authentic scientists would. However, these contributions were not properly shared with the community in a way that would allow other community members to value them as contributions.

Based on members' planning styles and hot spots, we think this support can be achieved by creating tools for groups to contribute in different ways, according to their preferences. In the latest revision of our software, we have created tools for groups to tell the story of their experiences. We believe this will give bricoleur groups like the Carb Junkies a more free-form venue for sharing their experience with the community, and it would also give planner groups like the Jaguars a better view of the bricoleur's contributions. We have also added a tool that allows learners to write *Explanatoids* or short explanations (Crowley & Jacobs, 2002) that they learn from their experiences. Learners will view all contributions (stories, explanatoids, and recipes with observations) in the form of a cooking magazine on the main page of the software. While groups like the Carb Junkies are not likely to listen to scientific results until they become relevant to their group, they might look for short hints or explanations if they were available.

Using others' stories and explanations to help with their dishes could help the bricoleurs to find value in science contributions and value as well, for the creation of explanations. According to Bruckman, "Sometimes the best teachers are not experts, but learners only one step ahead of you who are excited about sharing what they themselves have learned." (p. 65) (Bruckman, 1998). However, much like members of different professions coming together to work toward a common goal need places where they can communicate on common ground, so do learners with different learning styles (Gorman 2005). Perhaps the computer can serve as a "trading zone" for this communication: a place where exchange of information happens between members from various professions – in our case, members with various learning styles and interests (Gorman, 2005).

6.4. *Buy-in: how can we help different types of learners take on scientific reasoning goals?*

Pitts and Edelson define "buy-in" as learners' adoption of a project role and goal (Pitts & Edelson, 2006). In KSI, there are several different roles and goals learners can buy into – those of scientists and those of cooks. Both are legitimate. From our analysis, it seems as though the science group bought in to the KSI science roles and goals from the beginning (i.e. the role of an investigator and the goals of answering scientific questions). For this group, the Column question and group discussions that focused on designing experiments and discussing results were effective for helping them select variables to study and to begin thinking as authentic scientists about controlling variables (we could tell by whole-group conversations that this was true for other scientifically inclined groups). However, even the most scientific learners were still motivated first and foremost by cooking goals and needed days where they could do just that.

The bricoleur group bought in differently. They bought in to the roles and goals of cooks, making dishes they wanted. They couldn't buy in to the Column Question, as it wasn't personally interesting to them. Rather, they needed to quickly get to achieving their own goals. For this group, and for others like them, we may not be able to plan for their "buy-in," but we can have tools in place for when they get there. Providing these groups with links to relevant work of other groups would be a way of having the proper tools in place when they are at points where the help of others is needed.

7. Conclusion

Understanding the needs of the Carb Junkies and the Jaguars gives us insight as to how we can design better for learners across the interest and planning style spectra. We want to help all participants find their "hooks" into science. Our study is limited – the sample size is small and we focused on groups rather than individuals. However, our study of two very different groups suggests ways to hook and scaffold learners with differences along the two spectra we focused on: interest and planning style. The planner group, interested in science, immediately bought in to their role as cooking scientists, answering scientific questions. However, as they moved to less structured days, they needed more help and tools to continue to take on the role of cooking scientists. Once given freedom to perfect their own dishes, the least scientifically interested of our groups, the bricoleurs, found their hook into science through their own personal cooking goals. This group was rebelling against the science coming first, not against the science. The need with respect to sequencing of activities, facilitator scaffolding, and software functionality is to organize things so that everyone's hot spots are hit.

In order for this to happen, there are things all learners need. Computer support plays a large role in addressing these needs, supporting a community of learners doing authentic science. First, it needs to help learners build a shared history in their community, particularly allowing learners to contribute to the shared history base in different ways. Project-based learning emphasizes providing learners with choice in their artifact creation. Our results shed light on how to provide this choice with respect to learners' interests and planning styles. Specifically, we found that learners need free-form as well as scientifically-structured means of sharing and accessing their experiences and contributions with the community.

Secondly, computer support needs to help learners see the different parts of scientific inquiry. In the design of KSI, we concentrated specifically on finding flaws, making observations, and designing experiments. We found that learners needed help articulating the important parts of their experiences, making quantitative observations, and making plans for choice days. Quintana *et al.* (2004) point out several software systems that have been successful at this type of scaffolding. However, in designing this help for after-school and summer camp environments, the challenge becomes presenting it as an opportunity in the context of helping learners achieve their goals.

Thirdly, software needs to serve as a reification of learners' expertise, pointing out and highlighting learners' accomplishments and contributions. In accomplishing this, we need to design software so that individual expertise is recognized, appreciated, and used. In short, we are suggesting a new form of adaptable scaffolding. Whereas adaptable scaffolding has traditionally been adaptable according to learners' ability .(Guzdial, 1995), we are suggesting scaffolding that is adaptable to learners interests and learning styles.

In summary, this study shows that two things are important. First, the right functionality to help kids learn from each other, learn from their experiences, explore the science behind their cooking, and buy in to the cooking and science roles and goals is needed. Second, activities should be organized in a way that allows each set of learners to have success through using science at goals they are achieving, and this needs to happen before they lose interest. While we suggest several ways of addressing the first need, the second remains a challenge and an opportunity for future work. Appropriating (or gaining a disposition to use) what one has learned is just as important as learning itself (Boaler, 2002). It is our hope that helping learners "hook into" the science will help them to appropriate scientific reasoning in their everyday lives.

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