

Students' Discussions of Data:  
Affordances and Constraints of First and Second Hand Experiences

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## Abstract

Students develop scientific knowledge by actively engaging in scientific ways of knowing, such as asking questions, designing experiments and analyzing data (Driver, Asoko, Leach, Mortimer & Scott, 1994). Recent research literature (Germann & Aram, 1996; Lehrer & Schauble, 2002) and national standards (AAAS, 1993; NRC, 1996) call for students to engage in scientific inquiry practices, such as analyzing data. Yet scientific inquiry practices can be challenging for students. For example, studies in the literature report students have difficulty describing trends in data and rarely support their conclusions with specific evidence.

In this paper, we examine how students discuss and interpret data and whether these actions vary depending on the type of data they are using. More specifically, we are interested in whether students perform differently when analyzing first and secondhand data. Our data analysis focused on two curriculum units, chemistry in grade 7 and biology in grade 8, collected during the 2002-2003 school year from a mid-western urban middle school. We analyzed classroom videotape associated with lessons where students discussed first and secondhand data.

We identified a series of patterns in how students handled data or discussion around data in first and second hand learning experiences. We identified similarities in the following:

- identifying ownership of data,
- identification of patterns within the data,
- the creation of data based conclusions and
- use of content during discussion of the data.

Both types of experiences afforded the teachers and students opportunities to engage in these practices around the use of data. However, not all of the affordances were seen in both of these types of learning experiences. We observed differences in the following areas:

- discussion of limitations of data (first hand)
- use of analogies, examples, personal experiences (second hand)

Implications of our finds are discussed in regards to the use of first and second hand experiences in the design of curriculum materials and student learning.

**Students' Discussions of Data:  
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Students develop scientific knowledge by actively engaging in scientific ways of knowing, such as asking questions, designing experiments and analyzing data (Driver, Asoko, Leach, Mortimer & Scott, 1994). Recent research literature (Germann & Aram, 1996; Lehrer & Schauble, 2002; Wu & Krajcik, 2003) and national standards (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) call for students to engage in scientific inquiry practices. AAAS and the NRC in *Science For All Americans* (AAAS, 1989) and the *National Science Education Standards* (NRC, 1996) respectively, have called for “science for all” (AAAS, 1989) and for an increased engagement in scientific inquiry (NRC, 1996). The *National Science Education Standards* acknowledges that scientific inquiry can cover a wide range of activities—“some activities provide a basis for observation, data collection, reflection and analysis of firsthand events and phenomena. Other activities encourage the critical analysis of secondary sources—including media, books and journals in a library.” (NRC, 1996). In this paper we have chosen to focus on an analysis of a specific inquiry practice, analysis data derived from either first or second hand phenomena. We have expanded the NRC description of secondary sources to include data sets that students would not have access to without them being presented as secondary sources. We believe that this inquiry practice is key to being able to make meaning out of the investigations that students engage in within science classroom as well as in the issues that face them in their every day lives.

***Student Difficulties Analyzing Data***

Studies have shown that students have difficulty describing trends in data and rarely support their

conclusions with specific evidence. Instead, students often rely on their personal views, instead of the data at hand, when drawing conclusions from data (Hogan & Maglienti, 2001).

Furthermore, students have difficulty understanding that some degree of variation will always be present in data (Germann & Aram, 1996). When pressed, students can come up with a variety of reasons for why data variation may occur, but they do not consider measurement error when expressing their confidence in their conclusions (Masnick & Klahr, 2003). Students do not appear to think about error or limitations in data when they are analyzing data or drawing conclusions.

Kanari and Millar (2004) have shown that students have difficulties in understanding the role of experimental data and measurement in the scientific investigations that they have collected.

These studies have indicated that specific experimental situations can be helpful for students to begin to build an understanding of what experimental data, measurement and error means.

Additional studies have indicated that there is a difference in the type of science data that students use in school and the science that is used in science related work places (Aikenhead, 2005). Others (Chin et al, 2004; Duggan & Gott, 2002) have correlated this difference in what the procedural knowledge that comes with working with meaningful data/experiments and the isolated school science that students often experience in classrooms. We are interested in extending these studies by looking to see if the type of data in terms of first or second hand data, allowed students opportunities to develop an understanding about data and the use of data during scientific inquiry investigations.

### ***Defining First Hand versus Second Hand***

In this paper, we are interested in examining how students discuss and interpret data and whether

these actions vary depending on the type of data they are using. More specifically, we are interested in whether students perform differently when analyzing first and second hand data. Similar to Palincsar, Magnusson and colleagues (Palincsar & Magnusson, 2001; Magnusson, Palincsar, Hapgood, & Lomangino, 2004), we define first hand-experiences as when students investigate phenomena using various inquiry practices. Although Magnusson and colleagues define secondhand-experiences as when students “learn about and evaluate other’s investigations of the same or similar phenomena” (Magnusson et al, 2004 p. 318), we use a slightly broader definition. In K-12 science classrooms, students often cannot collect data for a variety of reasons such as the phenomenon are too dangerous (e.g. explosive chemical reactions), the phenomenon takes too long (e.g. natural selection), necessary equipment is too expensive (e.g. DNA sequencing), or various combinations of these reasons. Thus, our definition includes having students’ evaluate other’s investigations, but also experience evaluating data collected by other individuals.

Project 2061 Textbook criteria also discuss the importance of both first hand-experiences and secondhand experiences, which they refer to as indirect or vicarious experiences (Kesidou & Roseman, 2002). They argue, “If all experiences provided to students were firsthand, it would limit the number of examples that could be provided. Moreover, students should not be asked to reason only about phenomena they see firsthand, when in real life they will also encounter phenomena indirectly” (Kesidou & Roseman, 2002). Analysis of secondhand experiences occurs every day when individuals interpret data presented in the newspaper, in magazines, or on television. Furthermore, the analysis of second hand data recently has become increasingly important in science as the internet has made large data sets readily accessible (e.g. genomic data bases, and weather data bases).

*Affordances and Constraints of First Hand versus Second Hand*

Although both first and secondhand experiences have important roles in science and in science classrooms, there appears to be little empirical work about the affordances and constraints of having students engage in these two different types of experiences. For example, in a Delphi questionnaire of science experts about important ideas in science to include in science classrooms the analysis and interpretation of data emerged as one of nine themes. A number of the experts in the study hypothesized that first hand experiences were particularly important because students would be more interested in the data and it would provide an opportunity to discuss variation in data and different interpretations of data (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). Although these hypotheses may be correct, there is little empirical evidence to support them.

Recent empirical work by Magnusson, Palincsar and colleagues (2004) have suggested that there is a complex interplay between the sequence of first and second hand investigations that can impact student learning. In their study, they suggest that there might be a “preferred sequence and mode of investigation of contexts to support learning.” (Magnusson et al, 2004, p. 318). In their study, they argue for more research to be done in order to understand more fully what this interplay between first and second hand learning experiences might be.

In our study, our research design and questions are slightly different, We are interested in identifying what affordances and constraints that first and second hand learning experiences might have for students. We have not yet begun to examine the role that the sequence of learning experience might have on learning. In order to engage students in this type of learning new

curriculum materials need to be developed that support both teachers and students (AAAS, 2000; Kesidou & Roseman, 2002). We use two examples of materials that were developed in alignment with the national science standards in terms of both content and scientific practices to begin to examine how students handled different types of scientific data.

## **Method**

### ***Instructional Context***

In this paper, we examine the role of first and secondhand experiences in students' data analyses. Our analysis of student learning focused on the enactment of two curriculum units, chemistry in grade 7 and biology in grade 8 (McNeill, et al., 2003; Tzou et al, 2003) developed as part of the Investigating and Questioning our World through Science and Technology (IQWST) instructional materials development project. The 6-8 week chemistry unit, "How do I make new stuff from old stuff?" (referred to as "chemistry" or "stuff") engages students in the study of substances and properties, the nature of chemical reactions, and the conservation of matter. The 8- week biology unit, "What will survive?" (referred to as "biology" or "survival") engages students in the study of species' interactions in ecosystems, including structure/function, variation, competition, and natural selection. A major design feature of these units is the systematic and scaffolded use of various inquiry practices, particularly with respect to constructing evidence-based explanations, data analysis and interpretation, and interpreting representations. The materials also support teachers in their learning of these practices. We analyzed videotape associated with lessons in which students discussed first and second hand data.

The units were enacted during the 2002-2003 school year in one middle school located in a large mid-western city. In the city school district, over 90% of the students in the schools are African American and come from lower-middle to middle income families, however the school that this study occurred in was not typical of the city public schools. It is a K-8 magnet school, which students need to take a test to qualify to enter the school. The percentage of students that qualify for free and reduced lunch was 15.2%, which is much lower than the typical school. Similar to other schools in the district, the majority of students are African American. Although the school is not typical of district schools, it still has many of the issues that are often in urban schools (Lynch, 2000; Haberman, 1991).

Over crowding and access to materials is a major issue in the school where there are on average approximately 37 students in each classroom. Because of limitation in terms of classroom space (six lab tables in each classroom) and materials (such as hotplates and computers), when students worked in groups there were typically six students in each group in the classrooms observed for this study.

The study took place in two different classrooms in this same school. Ms. Carter enacted the chemistry unit with her 7<sup>th</sup> grade students. Mr. Davis enacted the biology unit with his 8<sup>th</sup> grade students. Mr. Davis also had a student teacher in the classroom who frequently taught the students, Ms. Stevens.

### ***Data Sources***

For this study, we examined three lessons from the chemistry unit, two lessons where students used data they generated (first hand experience) and one lesson where students used data that

was given to them (secondhand experience). We also analyzed three lessons from the biology unit, one lesson where students used data they generated (first hand experience) and two lessons where students used data that was given to them (secondhand experience). Each lesson lasted from one to five days for a total of fifteen days. All lessons were videotaped.

<b>Lesson</b>	<b>Discipline</b>	<b>Topic</b>	<b>First or second hand</b>	<b>Days</b>
Lesson 2	Chemistry	Solubility	first hand	2
Lesson 4	Chemistry	Density	first hand	2
Reader	Chemistry	Properties	second hand	1
Lesson 13	Biology	Variation	first hand	3
Lesson 14	Biology	Sexual selection	second hand	2
Lesson 16	Biology	Natural selection	second hand	5

Table 1: First or second hand experiences used during analysis of data

During full class discussions, the camera focused on the individual speaking, either the student or teacher, using a boom microphone. During group work, the camera focused on one group of students using a table microphone to capture student talk. All videos were transcribed.

### ***Data Analysis***

We coded the transcripts for each of the lessons to characterize students' discussions of scientific data. We developed the coding schemes from our theoretical framework and an iterative analysis of the data (Miles & Huberman, 1994). The coding scheme included codes for: data measurement, limitations of data, data source, data manipulation, patterns/trends, conclusions from data, consideration of content knowledge, connections across investigations, and use of illustrations. We selected these codes as being important in understanding how students worked with data in different types of learning experiences and as being shown in the literature as areas

students often have difficulty with when using data. One of these codes (data measurement) was only coded for in the first hand experiences as our definition of second hand data excluded this code for second hand experiences. Several of our codes had multiple criteria that were used to capture a complete picture of how students discuss specific types of data. These criteria were coded in one of two ways: presence or absence or a more detailed evaluation. For example, in the manipulation of data code, we had two criteria, criterion one was “discuss data” and criterion two was “manipulate data”. Discuss data was coded as a 0 or a 1 for students either did or did not discuss data. If students discussed the data, the discussion was then evaluated for the second criteria “manipulate data”. The codes for this second criterion are an example of our second way of evaluating in more depth. Here we evaluated the criteria for not only evidence of manipulating the data but also if the resulting representation was accurate and complete. In order to do this, we had three codes that we used: no representation or calculation was made (given a 0), a representation or calculation was made but it was not appropriate or complete (given a 1) and an appropriate and complete representation was made (given a 2). See Appendix A for details of all of the codes in our coding scheme.

In order to code the transcripts, we first split each day of a lesson into a series of episodes. An episode is a chunk of time that we identified by the teacher and student interactions and the focus of the class. When the classroom interactions shifted from full class to small group or from small group to full class, we classified this as a separate episode. We also identified a section as an episode if the focus of the conversation shifted. For example, during a full class discussion during the solubility lesson of the chemistry unit the teacher first demonstrated how to test the solubility of a substance and then shifted the conversation to a discussion of students’ predictions for the solubility experiment. We classified this full class discussion as two separate episodes.

Each day consisted of between one and four episodes for a total of forty-five episodes. The two authors coded episodes. We selected 20% of the episodes (9 episodes) to be coded independently by both authors. We selected these episodes to include at least one episode in each lesson across chemistry and biology and to include both full class and small group discussions. Our estimates of inter-rater reliability were calculated by percent agreements. Our inter-rater agreement was 92% with all disagreements resolved through discussion. The remaining episodes were coded by one or the other authors.

### **Findings**

Our findings are presented as patterns that were identified as a result of a comparison of the results of coding the first and second hand experiences across all of the categories. In addition, we looked for patterns within first hand and second hand experience across time. Both similarities and differences were identified when the data was analyzed in this manner. We were interested in identifying similarities and differences in how students engaged in handling data in these two different experiences.

#### ***First Hand Versus Second Hand Experiences***

##### Similarities between first and second hand experiences

In comparing the first and second hand learning experiences in two project based science curriculum, we identified four patterns that we saw across both types of experiences in each of the units. These patterns illustrate how students and teachers engaged in handling different types of data and discussing the data as part of the learning process. These patterns include: identifying ownership of data, identification of patterns within the data, the creation of data based

conclusions and use of content during discussion of the data. We discuss each of the patterns in detail below.

*Pattern 1: Identifying ownership of data*

In examining the videotape of the first and second hand experiences for instances of students and teachers referencing where the data came from, we saw that in both types of experiences students and teachers did identify the data. Students and teachers called out the data as belonging to someone using either explicit or vague labels in 16 episodes out of a possible 21 first hand experience episodes and 12 episodes out of a possible 24 secondhand episodes. We believe that both first and second hand experiences afford students the opportunity to claim or assign ownership of the data.

In the biology lesson on variation in populations, a first hand experience, Mr. Davis, one of the two teachers in the biology class instructs the class to “Take a look at your data. Let me remind you, we’re just trying to find a way where we can graph the class data” (Lesson 13, day 2). This was coded as an explicit reference to ownership of the data that was being used in the class discussion. Here the teacher creates an interesting distinction between what is the individual’s data and what is the class data. In the chemistry lessons, examples of vague references to data ownership were seen when students talked about their data. For example in the lesson on calculating the density of different substances, students talked about “our results were high” And that “everybody’s were high like that” indicating that there was a general acknowledgement of where the data came from but not calling out any of the data as belonging to one specific person or group. In other episodes during the chemistry unit, the class explicitly discussed ownership. An explicit discussion of where data came from was seen in the chemistry lesson where students

determined whether or not fat and soap were soluble in water or oil. Students worked in their group to determine if fat is soluble in water and referred to “our results” and “our difference”, indicating that they did the investigation and it is their results that they are using. (Lesson 2, Day 2)

Another example was seen in this same first hand experience lesson where the chemistry teacher called out the ownership of the data when talking to a student in a whole class discussion.

Ms Carter: right, the experiment that you did. Dante, you're going to get information from the experiment that you did. SO you should actually in your evidence refer to what you observed. You did the experiments the investigations. You all obtained the results based upon your verbal communications to my questions and your answers. You guys came up with the correct results....  
(Lesson 2, Day 2)

The teacher gave ownership to the individual student as well as his classmates by identifying the data that they will be using as evidence that they obtained and that they will now use in their conclusions.

A similar type of large group discussion was seen in a second hand experience lesson where Ms. Stevens, the student teacher in the biology class, called out the specific scientist by name, Mary Pietre, who collected the data that the students were working with in the lesson. “She measured and observed all the males she had, and just in the first season, she said, ok, this guys got a certain length of feathers, this one's got this length, this one has certain size eyespots.” (Lesson 14, Day 1). In this conversation, the teacher also highlights the fact that the scientist is a female and how this might have allowed her to bring a unique perspective to the study that she conducted.

Ms. Stevens: So what LaSonya said, basically what LaSonya said is that back when Darwin was doing his research, in the human society, men were in control. Men were the researchers and in human society at the time, males were more

dominant, so they kinda had more power in choosing a mate, and marriage was less of a female's decision. But she just said something else. What did she say she thinks is going on here? Who's making the choice here?

Students: Females!

Ms. Stevens: She thinks the females are making the choice here. And who is, what is this researcher who had this idea? Was she male or female?

Students: Female!

Ms. Stevens: She's a woman. Interesting thing happened when women started coming into the field of looking at animal behavior. All of a sudden, we have a different perspective. And the women are saying, wait a minute, the males aren't the ones choosing the females here. They're doing this great big song a dance, and the females are the ones that are making the choices. All of a sudden, these ideas of female choice are coming into the picture. (Lesson 14, Day 1).

This conversation suggests that not only did the class identify who collected the data, but there is also an acknowledgement that the individual collecting the data can influence what type of data is collected and what types of patterns are observed. Data identification occurred in both small group and full class discussion (4 times in small group, 12 times in whole class discussion) and in both first and second hand experiences. While both types of experiences allow this type of ownership claim to be made and used in meaningful ways, this finding of claiming ownership needs to be further examined to see if this is a predominantly teacher led practice or if this is something that students were doing on their own initiative as well. Our pilot data analysis indicates that this is something that is being done by both students and teachers and in the observed classrooms was an important classroom practice. However, it would be interesting to see if the teacher initiates this type of conversation more frequently than students and if this happens in other classrooms as well. We are interested in examining this because we believe that for students to engage in meaningful learning experiences they need to be willing to claim ownership of the learning as evident by acknowledging ownership of the data that they are working with in the lesson. In addition, this ownership is an indication that students may

understand that science is not “fact” but rather generated knowledge or understanding about a phenomena that is constructed by people-- some thing that scientists at all levels can participate in.

*Pattern 2: Identification of patterns within the data*

In both types of experiences, students engaged in looking for patterns in their data.

Std 2: What the heck did it do?

Std 3: Nothing.

Std 5: Don't turn it upside down, because it doesn't close.

Std 2: It's all greasy.

Std 3: The fat is not soluble in water. It just clogged up the tube.

Std 5: Fat is not soluble in water, but it is in oil. I am so smart.

Std 3: Ok, it's not soluble in water, but it's soluble in oil.

Std 4: Alright, we're done. That was easy. This is soap in water, right (holding test tube)? How can you tell what this is?

Std 5: Ok, so that's. Is that the one you just did?

Std 3: No.

Std 5: That's the soap in water. Soap is not soluble in water or oil. But fat is soluble, but fat is soluble in fat.

Std 3: So we have all our results and we found out that fat is not soluble in water but it's soluble in oil and soap is soluble in water and not soluble in oil.

Std 4: (holding both test tubes) See, look at the difference. This is the fat in oil, and this is the fat in water. See our difference?

Std 2: I wanna get some of these experiments at home. (Lesson 2, Day 2)

In this first hand chemistry example, students are identifying patterns within their experiment, an

affordance of working with their own data. Initially they have an inaccurate observation (that soap is not soluble in water) but then later in the exchange, this observation is corrected and the students agree on the correct pattern that fat and soap have different solubility in the “solvent.” This type of identification and understanding is important for students to do in order to make meaning out of the hands on investigations that they are doing as part of the extended inquiry unit. We conjecture that it is important for students to make this link and be able to transition between observations and patterns. Having students make observations that lead to patterns will allow them to begin to develop data based conclusions.

It is interesting that in this example, students comment on wanting to “get some of these experiments at home.” This type of comment warrants further examination. It is similar to the pattern before where we talked about ownership of the data. Here the idea that students want to repeat the experiment at home is an indication that they are taking ownership of the experiment and want to share the experiment outside of the school science environment potentially with other family members or friends.

In the second hand biology lesson, students also identified patterns within the data that they were looking at in order to develop an understanding of sexual selection. This is illustrated in the excerpt below:

Ms Stevens: Ok, so it's like we were saying that their tails tend be longer. Within those that survived though, did the ones that reproduced the most always have the longest tail?

Students: Yes noooo

Ms Stevens: Why no?

Student1: Because number 11 had 16 mates but it's tail was only 137 centimeters but the one that's tail was 119 and 120 centimeters

Ms. Stevens: Ok, another one someone noticed was that there was actually another male, number 2, he mated half as many times as number 11, and he actually had the same amount of eyespots and a longer tail. So I just wanted to point that out, that you can get variations, right? Cause we're working with a natural system. But in general, just like you all noticed right off the bat, in general, the males that survived had longer tails and more eyespots. Yeah?

Student 2: Uh, the eyespots on the peacocks with 147 or less eyespots died.

Ms Stevens: So nobody with more than 147 eyespots survived?

Student: No, died.

Ms. Stevens: No, I just flipped what you said. Nobody with more than died. Ok, you said it right and I said it wrong. (Lesson 14, Day 2)

In this exchange, the teacher and students are identifying patterns within their data that examines why there was an increase in the number of eyespots in a peacock population. This exchange is one of the teacher modeling how to analyze data and to use it in a meaningful way. Here the teacher is showing kids that they need to compare different data, look at the variation seen within the data, and make meaning out of this variation. These two types of exchanges illustrate how investigations using data can be used effectively in a range of different settings and teaching purposes.

### *Pattern 3: Creation of data based conclusions*

In all five lessons we examined, students frequently based conclusions on data that was given to them or collected by them as a result of an investigation. This finding is in contrast to the literature where it is reported that students have difficulty in using data to create their conclusions (Kanari & Millar, 2004). Though we did see some instances when students did not base their conclusions on data suggesting that this practice was not always easy for students. We

believe that both first and second hand data can be used by students to create data based conclusions. In both types of experiences across both content units, students tried to make data based conclusions. In the exchange below, the students discuss the importance of using different pieces of evidence to make conclusions.

Ms. Carter: What do you guys think, you think you have enough evidence?

Student 1: yes.

Ms. Carter: Why?

Student 1: Because in this experiment and in the last experiment, we proved they don't have the same melting point or density.

Student 2: But the density by itself doesn't, because the densities are 0.9 and 0.8. The density by itself don't. Cause they're so close together and like error. But from past experience, plus the density, it does. Cause by itself it doesn't because 0.9 and 0.8 are pretty close together. Ya'll hear what I'm saying. (Lesson 4, Day 1)

In this example, students discuss why they believe that they have enough evidence to make a conclusion about why the two substances that they are investigating are in fact different substances. In reading the exchange, one sees students talking about what makes good evidence and how their data can be used to justify their conclusion. Using density by itself is not sufficient, but if they also use their other data (i.e. color, hardness, solubility, and melting point) they can conclude that they are two different substances.

In the second hand biology example shown below, one sees students drawing conclusions that reference specific data.

Student: I didn't write this, this is what I was gonna write, I was real close. I was gonna write that I think they have such elaborate tails for the sole purpose of being able to attract a mate and I thought that because of this chart right here cause they had a lot of mates. More mates than the dead males. And the tails and the eyespots were longer and greater in number. (Lesson 14, Day 2)

In both first and second hand experiences, students had the opportunity to draw data based conclusions. This practice was identified in both types of lessons across both content units indicating that type of experience did not impact the creation of data based conclusions by the students.

*Pattern 4: Use of content in discussions*

In both first and second hand experiences, students and teachers draw on content to help frame the discussion. In the chemistry second hand lesson, students discuss whether or the data that they have been given in a table shows that the substances are different or the same. In the discussion, one student comments:

Otherwise, they both do not have – they both – it depends if they are the same substance if they would show other properties. All of its properties have to be the same for it to be the same substance, but they ain't showing all the properties of it. So it depends – to me. But they are showing in the chart – I said it is a substance. I said it was the same substance from the chart though. (Lesson 6)

In his comment, he references the importance of knowing multiple properties, which are not shown in the table, to determine if the substances are the same or not. The students continue to pull on content knowledge about what determines if substances are the same or not throughout their discussion about the data table.

Student 3: Scientists, I think, I think - they use um several different properties because one or two you ain't going to know if it is the same substance. Say like color and hardness, you don't know if it is the same substance if they both –

Student 1: Where are you seeing hardness at (points to the table)

Student 3: I am saying if -

Student 1: (can't hear)

Student 2: He is using it as an example.

Student 3: I am saying if color and hardness is the same you wouldn't know if it is the same substance because they ain't list all of the properties. They are only the same substance if all of the properties are the same. You would have to know the density, the melting point, the solubility – everything.

Student 2: Ok. So using more than one property tells you – I mean

Student: Using one or two properties doesn't tell you, doesn't tell you –

Student 2: Doesn't make sure. I mean.

Student 3: Doesn't tell you –

Student 2: Exactly –

Student 3: Exactly if they are the same substance.

Student 2: Ok. (Lesson 6)

Later in the lesson, the teacher echoes this same thought when she comments:

Ms. Carter: However, when you take more properties, according to G, into consideration you may find that a property differs; therefore, you can conclude that possibly they are not necessarily the same substance. (Lesson 6)

This is in conflict with what is reported in the literature. Studies have shown that students often do not use content knowledge to analyze data or to draw conclusions and that instead they depend on their own personal experiences to help support them in their ability to reason through data and develop a deeper understanding of the content being taught (Metz, 2000). While we did see students using domain specific content knowledge to make meaning of their data in both first and second hand settings, we did not see this practice all of the time and believe that further examination is needed to fully understand why this occurs in some instances, but not in other instances.

### Differences between first and second hand experiences

In comparing the first and second hand learning experiences, we also identified two patterns that were distinct for each type of experience. These patterns suggest that first hand and secondhand experiences have different affordances and constraints. These patterns were seen in discussion about limitations of the investigation and the use of illustrations and connections to personal experiences. An increased level of discussion about the limitations of a specific investigation was seen in the learning situations based in first hand data, though some discussion was seen with the second hand data. The use of illustrations and connections to personal experiences was seen at a greater level with the second hand data. We discuss these patterns in more detail below.

#### *Pattern 1: Limitations of investigation*

First hand data allowed the students to discuss limitations to the investigation and to the data that was being examined more often than the second hand experiences allowed. Two different types of limitation of data discussions were identified as being supported by the use of first hand data: execution and measurement limitation. Execution limitation included discussions about difficulties with carrying out the investigation and measurement limitations included discussions about difficulties with collecting the necessary data.

#### *Execution limitation*

The code “execution limitation” was meant to capture any discussion about difficulties with completing the experiment, which could have resulted in inaccurate data. This could include a discussion of problems in the set-up or execution of an experiment. This discussion could have been focused on broken equipment or other issues students or teachers chose to highlight. For

example in the chemistry unit, one instance of this was seen in the first hand experience lesson where students determined the solubility of lard. In carrying out the investigations, students comment “That’s because he kept it at the top but anyway, it didn’t dissolve. It didn’t dissolve” and then later in the lesson the students explained their results by saying “Cause we ain’t poured it right, we ain’t poured it. We didn’t do the right amount last time.” (Lesson 4, Day 1). Students have identified two possible reasons why their experiment might not have turned out the way that they anticipated.

In the second hand biology lesson where students are looking at a scientist’s data about sexual selection, students and teacher talk about not knowing how the data was collected as an issue.

Student: Well, I have something else to say. I don’t think it’s fair to compare the surviving males to the dead males.

Ms. Stevens: Ok, why not?

Student: Because how do we know the dead males were fully grown before they died. They might have just had a bad day and they would have grown up to have a big tail.

Students: (Laughter)

Ms. Stevens: SO they didn’t get all the way to full grown of full length? That’s really important though, and that’s a great point to bring up, and with research, that would be a great question that you would ask the researcher, to make sure the validity of their data. Unfortunately, we can’t ask her, so we have to assume that these are full grown. But that’s a great point. Maybe they weren’t full grown, but instead what you’re calling a teenage peacock. They haven’t gotten to their full length yet. We also have the data from the other two charts to work with for our conclusions. But that’s a great point. As far as questioning the data-that’s an excellent thing to always do. Look at the method, just like Anthony did. Just as Anthony did, you look at the method and see if the result makes sense and they did everything right, or if there’s a loophole, ok. You should always be doing that, so that was excellent. So some of the commonalities I’m hearing are female preference, the length of the feathers, the eyespots. Excellent data was brought up about that. What other things or commonalities were we hearing throughout your conclusions? (Lesson 14)

This type of discussion happened in both the first and second hand lessons but it happened more frequently in the first hand lessons than in the second hand lessons. This was coded for 6 times in the first hand lessons and only 2 times in the second hand lessons. There were similar number of episodes coded in both the first and second hand lessons (21 and 24 first hand and second hand episodes respectively). Our data suggests that either the teacher or the students can initiate this discussion. Of interest to us is the frequency that students bring this up during discussion about their own data without the prompting of the teacher. This type of questioning and discussion of possible limitations is important in understanding the nature of what reliable data is and the nature of science.

#### *Measurement limitation*

In examining the category measurement limitation of specific measurements, we saw six different instances of this category being coded across three first hand lessons (a total of 21 first hand episodes). This code indicated that either the students or teacher acknowledged that the data could have been measured or collected incorrectly. This was not seen in the transcripts from the three second hand lessons (24 episodes). In the first hand lessons, both full class and small group episodes had instances of this type of discussion occurring. For example in the lesson where students determined the density of two substances, students repeatedly mentioned the limitations of the data that they were collecting. Students are attempting to determine the density of a block of lard. As students begin to collect their data that they will use to determine if the two substances are the same or different, students can be heard commenting that “This scale is off.” (Lesson 4) and that “That the scales broken. That’s probably why we got these measurements.” (Lesson 4). Students also acknowledge that human error can be part of the issue with their data

collection as is seen in a comment that a group of students made about how their teacher could have impacted their result. “If she cut it evenly...” (Lesson 4).

In the biology first hand experience lesson, the students and teacher have an extended conversation about how data that they are generating needs to be collected so that the investigation is a valid and meaningful investigation.

Mr. Davis: Let me have your attention! Let me have your attention, before we go any further. Shaun! Marcus! Lavel! Sit down. Now, Anthony has a hypothesis that the data is being collected twice. I don ‘t quite understand what Anthony is talking about, and I ‘m going to ask Anthony to present before the class to see if we can help him figure out what ‘s going on.

Anthony: This is the data from my group. This is one group ‘s data. If I use this data and the other two people in my group use this data, that ‘s counting this data three times. (Lesson 14, Day 1)

The teacher and students continue to discuss how the data should be collected so that the investigation can be done in an interpretable way.

These examples illustrate the importance of having students realize that data needs to be collected in a systematic way and that different variables can impact the reliability of the data collected. Research has been done that shows the importance as well as the difficulty in having students recognize that different types of variation can exist in data. (Mesnick & Klahr, 2003).

Understanding these issues will help students use the appropriate data to make conclusions based in their data. We see in our study that students are acknowledging the existence of variation and attempting to control for it in certain situations and acknowledge it when drawing their conclusions.

*Pattern 2: The use of analogies/examples/personal experiences*

A pattern that we saw between the first and second hand experiences was that in the second hand experiences, teachers and students used analogies, examples and personal experiences more frequently to help make their conclusion or explain the content of the lesson. The use of analogies and examples occurred 5 times in first hand and 8 times in second hand experiences. In the second hand experience biology lesson, the teacher used the following example to help explain mate preference:

Student: I have a question.

Ms Stevens: Ok?

Student: What if someone likes that one that's not really elaborate? Like what if they would prefer a less attractive one so the other ones can't take him?

Students: [laughter]

Ms Stevens: Ok, well you're getting into a whole other strategy. So there's one thing you look for with a desirable male might be how good he looks or how healthy he looks. Another thing, though, is behavior. Are you going to have to compete with other females for that male? So are you going to fight for Brad Pitt, or are you going to settle for, I don't know, Woody Harrelson? You would settle for Woody Allen because there's less people competing for Woody Allen than Brad Pitt. So listen, that's something we're not going to get into. But that brings up the great question of the complexity of sexual selection. And I only go there because I want you to understand that we're just looking at a little picture of a big issue, ok (Lesson 14)

In this example, the teacher is using examples of actors that she thinks the students are familiar with to try and describe how mate selection might occur. This example illustrates how difficult it is to create accurate and complete examples for complex biological concepts. This same teacher uses a different example to illustrate for her students a biological trade off that is often seen with sexual dimorphic characteristics.

Ms Stevens: So these males are so healthy. Imagine, like, there are two people standing there and they've got two backpacks on. One of the backpacks is heavier. That is our peacock with the longer tail...SO he's so healthy that even though he's got this extra long tail, he still can outrun the fox, or he still can keep himself away from it. So he's that much more healthy than the one with the shorter tail. Does that make sense? He's really healthy. Anything else? You were going to bring that up too? (Lesson 14)

Here the teacher is using a situation that middle school students are familiar with and can understand—the use of heavy backpacks. The use of personal experiences or connections to prior lessons or experiences was seen more frequently in the second hand experiences in both the chemistry and biology units. Use of personal experiences in conclusions was seen 2 times in the second hand and none in the first hand.

One possible interpretation of the finding that first hand experiences rarely included the use of illustrations and personal experiences is that students are focusing more on the actual data in first hand experiences or perhaps because they are responsible for collecting the data makes it more engaging and meaningful for the student. This then can be compared to the idea that students might not be as familiar with the second hand data because they did not collect it and so need to draw on other funds of knowledge to help understand what the data means. While the connections to personal experiences and to analogies/examples that students are familiar with is an affordance of the second hand experiences, it also is potentially a constraint of the second hand experience. It is an affordance in that students are able to make connections to their lives outside the science classroom and it can help anchor their learning in their lives. But it also needs to be viewed as a constraint as the examples used might not be as accurate or appropriate and could lead to a misunderstanding of the science being discussed.

In examining first and second hand data experiences, we identified four similar patterns in first and second hand experiences that afforded students the opportunity to engage in a meaningful

use of data. This indicates that both types of learning experiences can provide similar opportunities to engage in learning through data at a gross level. However, not all of the patterns that we identified were seen in both experiences—two distinct patterns were seen in our analysis that indicated that each experience has potential affordances that the other does not. Because of this distinction, careful selection of the type of experience is needed in order to ensure that students engage in a variety of different types of data discussion.

### **Patterns over time analysis**

We continued our analysis by looking at trends within the first or second hand experiences across time. We represent our findings using two examples, one from the biology unit and one from the chemistry unit. These examples are representative of what was seen during this analysis. In the tables below, codes have been collapsed so that the different boxes represent only the presence (solid black) or absence (hatched lines) of discussion about the different categories. We have not attempted to assign a correct or incorrect value to the discussion. The representations depict the patterns of discussion that occurred over time.

*Patterns in First Hand Experiences Over Time*

Table 1 represents the patterns in the first hand experiences, exemplified by the chemistry lesson on solubility.

Codes	DAY 1				DAY 2			
	D1 E1	D1 E2*	D1 E3	D1 E4	D2 E1	D2 E2	D2 E3	D2 E4
#1 Data Measurement	■	■	■	■	■	■	■	■
#2 Limitations of data	■	■	■	■	■	■	■	■
#3 Data Source	■	■	■	■	■	■	■	■
#4 Data Manipulation	■	■	■	■	■	■	■	■
#5 Patterns/trends	■	■	■	■	■	■	■	■
#6 Conclusions form data	■	■	■	■	■	■	■	■
#7 Consideration of Content	■	■	■	■	■	■	■	■
#8 Connections to investigations	■	■	■	■	■	■	■	■
#9 Use of illustrations	■	■	■	■	■	■	■	■
Type of group	Full	Full	Group	Full	Full	Group	Full	Full

Table 1: First hand Chemistry Lesson: Solubility

\* Episode 2 was a portion of the class where the teacher led a demo and students made predictions about what their results of their individual investigations would be. No data codes were seen during this portion of the class.

Early in the first hand experience lesson (Day 1, episode 1), one sees a discussion about data measurement and possible limitations of the investigations that the students are carrying out.

There is also an initial grounding in the content that students would be learning about during the investigation over the next two days. This discussion then changes to include discussions about where the data is coming from (identity code 3), what the data is (data code 4) and what conclusions can be made (conclusions code 6). This shift in discussion corresponded to a shift in activity where at first the teacher introduced the lesson and then students completed the activity and there was a greater focus on the procedure and the “doing” of the experiment. In the final episode of the lesson, we see that the conversation includes all of the codes, except limitations. At the end of the lesson, the teacher focused the conversation on the meaning making which

included discussing patterns and conclusions as well as drawing on content knowledge, connections across investigations and even illustrations, which we rarely saw in first hand discussions. This type of discussion sequence moving from the doing of the investigation to the meaning making of the lesson is a pattern that one would expect to see in a classroom where students and teachers are engaged in hands on and minds on inquiry learning.

***Patterns in Second Hand Experiences Over Time***

Table 2 depicts the patterns in the second hand experiences exemplified by the biology lesson on sexual selection.

Codes	DAY 1			DAY 2		
	D1 E2	D1 E3	D1 E3	D2 E1	D2 E2	D2 E3
#1 Data Measurement	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#2 Limitations of data	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#3 Data Source	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#4 Data Manipulation	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#5 Patterns/trends	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#6 Conclusions form data	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#7 Consideration of Content	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#8 Connections across investigations	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
#9 Use of illustrations	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines	Diagonal lines
Type of Episode	Full	Full	Full	Full	Full	Full

Table 2: Second hand Biology Lesson: Sexual Selection

In the second hand example, one sees a similar pattern of how data is discussed and handled over time as compared to the first hand experience lesson with some key differences. If one looks at the trends of classroom discussion, one sees an initial discussion that is based in the content (content code 7) of the lesson (sexual selection) with connections to prior lessons and experiences. This content discussion continues to occur throughout the lesson, this emphasis on content throughout was not seen in the first hand experience lesson where students transitioned into a doing of the experiment portion of the class focusing on measurement (code 1, table 1).

The use of illustrations occurs more frequently throughout compared to the first hand experience. In the second hand experience, the class entered into a discussion about data (code 4), possible patterns (code 5) and conclusions based in data (code 6) with no discussion on possible limitations of the investigation or measurement. The second day of the lesson is spent predominantly discussing the data, possible patterns within the data and conclusions based on the data.

In the second hand lesson example, an extended discussion of data measurement is not seen as one might expect since the students are not collecting the data. The only limitation discussion (code 2) that is seen is a brief discussion on the design of the investigation that led to the data set being collected. Perhaps due to this as well, there is only limited discussion about the possible limitations of the investigation.

### **Implications**

We identified a series of patterns in how students handled data or discussion around data in first and second hand learning experiences. We identified similarities in the following:

- identifying ownership of data,
- identification of patterns within the data,
- the creation of data based conclusions and
- use of content during discussion of the data.

Both types of experiences afforded the teachers and students opportunities to engage in these practices around the use of data. However not all of the affordances were seen in both of these types of learning experiences. We observed differences in the following areas:

- discussion of limitations of data (first hand)

- use of analogies, examples, personal experiences (second hand)

We believe that we saw affordances across both learning experiences in terms of students' discussions about data for several reasons. The unexpected amount of ownership that students voiced in regards to their data could have been due to one of the design principles that was used in designing the curriculum materials that were used in this study. The units were designed to be representative of authentic learning tasks for the students. Because of this, it is possible that students were willing to claim ownership of their data and to the doing of the science.

Students frequently do not base their conclusions on data (Hogan & Maglienti, 2001). The high number of instances of data based conclusions in our study could be due to the scaffolded nature of the curriculum. Studies have shown that it is important to support students in inquiry tasks (White & Frederiksen, 1998). When students are supported in meaningful ways, it is possible for students to engage in the practices that are being asked of them. We saw this in our analysis of the data based conclusions in both the first and second hand examples.

The use of content in data discussions can also be linked to the curriculum and the school culture that this study took place in—the curriculum does connect the content with the activities that the students are doing. Emphasis has been made to make the lessons more minds on and hands on by using a learning-goals-driven design model to align all activities, instruction, and assessments (Reiser, Krajcik, Moje, & Marx, 2003). These curricula are standards based units, with the learning activities closely linked to key learning performances. If this link is clearly present, students and teachers may be more likely to connect the activities to the appropriate content knowledge. The fact that students when analyzing the data, are using this content knowledge is something that we don't see in all cases. We are interested in examining why it happens in the

instances that it does.

However, our analysis indicates several differences in first hand and second hand experiences that should be considered during curriculum design. Although previous work has found that students often do not consider error or limitations when making conclusions about data (Masnick & Klahr, 2003), we found that this occurred quite regularly during the first hand experiences. If the goal of a unit is to help students understand limitations, it may be important to engage students in first hand experiences. In the second hand experiences, we saw that students used personal experience more often. While this is positive and is integral to student learning, we were concerned about the accuracy of some of the examples. This brings up the question of how do you help teachers and students make accurate connections to everyday phenomena.

When we examined the pattern of data based practices within a lesson, we saw that in the first hand experiences there was a pattern of emphasis on the doing of the investigations followed by a period of meaning making about the activity. In doing this type of lesson, there needs to be time allotted for the completion of the investigation. Although students' conversation did not focus on the meaning making during this aspect of the lesson, this type of activity may still be important for students to construct their own understanding. Further study is necessary to understand the value of the "doing" part of the lesson. In the second hand experiences, there is a shift in the discussion pattern as the teacher and students can engage in discussion about the data sooner than in the first hand experience. One implication of this might be that the second hand experiences could take place in less time, but this was not the case in our study. Our first and second hand lesson took approximately the same amount of time. In the biology unit, the second hand data was used because the curriculum developers want students to have access to data that

they could not possibly have access to as first hand data. The second hand data that students worked with were used to illustrate sexual and natural selection. Both of these examples would not be feasible to explore in a typical middle school classroom due to length of time and expense that would be required for a first hand experience. It is important to realize that this data allowed students to see patterns and draw conclusions using rather complicated second hand data sets.

This study is different from previously reported studies looking at the differences between first and second hand data (Magnusson, et al 2004), in that not all of the first hand experiences had similar second hand experiences. The use of each of the experiences was used to fulfill a specific learning goal. Because of this, it is important to keep in mind not only the affordances that each type of learning provides, but what the specific learning goals are for the students.

We need to expand this study past this one school. We understand that we carried this study out in two classrooms that are not typical of urban schools even though they share commonalities with other classrooms in the same district. We are interested in carrying this study out in other schools to see if we still see the same affordances/constraints of first and second hand data.

## References

- Aikenhead, G. (2004). Science Based Occupations and the Science Curriculum: Concepts of Evidence, *Science Education*, 1-34.
- AAAS. (2000). *AAAS science textbooks conference CD-ROM resource*. AAAS Conference on Developing Textbooks That Promote Science Literacy [online]. Retrieved August 16, 2004 from <http://www.project2061.org/meetings/textbook/literacy/cdrom>.
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- Duggan, S. & Gott, R (2002). What sort of science education do we really need? *International Journal of Science Education*, 24, 661-679.
- Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5-12.
- Germann, P. J. & Aram, R. J. (1996). Student performances on the science processes of recording data, analyzing data, drawing conclusions, and providing evidence. *Journal of Research in Science Teaching*. 33(7). 573-798.
- Haberman, M. (1991). The pedagogy of poverty versus good teaching. *Phi Delta Kappan*, 73, 290-294.
- Hogan, K. & Maglienti, M. (2001). Comparing the epistemological underpinnings of students and scientists' reasoning about conclusions. *Journal of Research in Science Teaching*. 38(6). 663-687.
- Kanari, Z. & Millar, R. (2004) Reasoning from Data: How Students Collect and Interpret Data in Science Investigations, *Journal of Research in Science Teaching* 41(7), 748-769.
- Kesidou, S. & Roseman, J. E. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching*, 39, 522-549.
- Lehrer, R., & Schauble, L. (Eds.). (2002). *Investigating real data in the classroom: Expanding children's understanding of math and science*. New York: Teachers College Press.
- Lynch, S. (2000). *Equity and Science Education Reform*. Mahwah, New Jersey: Lawrence Erlbaum Associates.
- Magnusson, S. J., Palincsar, A. S., Hapgood, S., & Lomangino, A. (2004). How should learning be structured in inquiry-based science instruction?: Investigating the interplay of 1<sup>st</sup> – and 2<sup>nd</sup> –hand investigations. In Y. Kafai, W. Sandoval, N. Enyedy, A. Nixon & F. Herrera (Eds.), *Proceedings of the sixth international conference of the learning sciences* (pp. 310-317). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Masnack, A. M. & Klahr, D. (2003). Error matters: An initial exploration of elementary school children's understanding of experimental error. *Journal of Cognition and Development*, 4(1), 67-98.
- McNeill, K. L., Lizotte, D. J, Harris, C. J., Scott, L. A., Krajcik, J., & Marx, R. W. (2003, March). Using backward design to create standards-based middle-school inquiry-oriented chemistry curriculum and assessment materials. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.
- Metz, K (2000). Young Children's Inquiry in Biology: Building the Knowledge Bases to Empower Independent Inquiry. In J. Minstrell and E vanZee (eds) *Inquiring into Inquiry*

- Learning and Teaching on science* (pp.371-404). Washington DC: American Association for the Advancement of Science.
- Osborne, J. Collins, S., Ratcliffe, M., Millar, R. & Duschl, R. (2003). What “Ideas-bout-science” should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40(7), 692-720.
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- Palincsar, A.S & Magnusson, S.J. (2001). The interplay of first-hand and text based investigations to model and support the development of scientific knowledge and reasoning. In S. Carver & D. Klahr (Eds), *Cognition and Instruction: Twenty-five years of progress* (pp. 151-193). Mahwah, NJ: Lawrence Erlbaum Associates.
- Reiser, B. J., Krajcik, J., Moje, E. B., & Marx, R. W. (2003, March). *Design strategies for developing science instructional materials*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.
- Tzou, C., Hug, B., Reiser, R., Dodeck, J., & Finn, L. (2003, March). *Teaching about Ecosystems in a Project-based Curriculum: Promises and Challenges*. Paper presented at the National Association of Research on Science Teaching, Philadelphia, PA.
- White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16(1), 3-118.
- Wu, H-K & Krajcik, J. (2003, March). *Inscriptinal practices in inquiry-based classrooms: How do seventh graders construct and interpret data tables and graphs?* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

## Appendix A

## Data Codes:

<b>Code #1 Data measurement – only first Hand Experiences</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Accuracy	0	All students' data measurements are inaccurate during the episode. Note – data measurements include mass and height, but not density. Density falls under data manipulation.
	1	Some of students' measurements are accurate during the episode, but some are inaccurate. Students discussion ends with agreeing on inaccurate data or no clear resolution
	2	Both inaccurate and accurate data are discussed. Episode ends with agreement on accurate data.
	3	All students' data measurements are “accurate” in that they are appropriate results for the particular investigation. Accept student data with a 20% error <ul style="list-style-type: none"> <li>○ Solubility – soap in water, not oil; fat in oil and not soap</li> <li>○ Melting Point – soap greater than 100; fat actually ~65. Accept 52-78</li> </ul> Density – Fat – 0.92, accept 0.74 – 1.10; soap – 0.84, accept .67 – 1.0
Completeness	0	Students' data is missing all measurements.
	1	Students' data includes some measurements, but is missing others
	2	Students' data is complete.
Agreement	0	Different students offer different measurements. At the end of the episode, there is not consensus – different students still have different measurements.
	1	During some parts of the episode there is disagreement, but there is resolution by the end.
	2	The group of students or whole class agree on the measurement or data set during the entire episode
	3	Teacher tells class the “correct” answer

<b>Code #2 Limitations of Data</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Design Limitation	0	Students do not discuss any limitations in the data.
	1	Students discuss that there is other data that would be helpful in the analysis. They do not need to specifically say “design”, but they need to talk about specific other data that would be helpful to have. Or if they suggest another set-up for the experiment.
Execution Limitation	0	Students do not discuss any difficulty with completing the experiment.
	1	Students discuss problems in the set-up or execution of an experiment, which could have resulted in inaccurate data. This can include discussion of broken equipment (i.e. broken scale)
Measurement Limitation	0	Students do not discuss any difficulty with measuring.
	1	Students discuss that the data could have been measured incorrectly, such as reading a thermometer, ruler or balance incorrectly.
Representation Limitation	0	Students do not discuss any difficulty with representing data.
	1	Students discuss that the data could be represented in different ways or that there are problems or limitations with the current way that it is represented

<b>Code #3 Data Source</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Identify	0	Students do not mention where the data came from.
	1	Students vaguely discuss where the data is from – students only use pronouns such as “they” collected it or refer to it as “our” data.  1 <sup>st</sup> – we/our/I/my connected to specific data 2 <sup>nd</sup> – “they” connected to either specific data or general data
	2	Students explicitly discuss that someone else collected the data or that they collected the data in class.  1 <sup>st</sup> – general discussion about “our results”, naming data, claiming ownership, possessiveness, calling out of data by the teacher or by the students, labeling data (more than just normal talk)  2 <sup>nd</sup> – Talk specifically about who else collected the data - “scientists” “the other class”

<b>Code #4 Data Manipulation</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Discuss Data	0	Students do not discuss the data. If students state data (in list form) not a discussion
	1	Students discuss the data. They discuss their observations, measurements, or manipulation of data.
Manipulate data	0	Students do not make representations or calculations. Filling in an existing table counts as a 0 – they are not manipulating the data.
	1	Students do make representations or calculations, but are not appropriate or complete. <ul style="list-style-type: none"> <li>○ By not complete, we mean they have not thought of or done something that they should have.</li> </ul> <p>Difference between 1 and 2 on the finch data is if it is random or if it is purposeful</p>
	2	Students make appropriate and complete representations or calculations. They can receive a 2 if it is appropriate and complete, but not finished. Ex. Grasshopper graphs take multiple days to complete

<b>Code #5 Patterns/trends</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Identify patterns	0	Students do not mention any patterns
	1	Students mention patterns in data Trend in data – densities are different or long legs survive
Accurate patterns	0	Students inaccurately identify patterns
	1	Students identify some accurate and may also include some inaccurate patterns <ul style="list-style-type: none"> <li>○ Patterns are not complete. This may be because they do not yet have all of the data necessary to determine a pattern.</li> </ul>
	2	Students identify accurate patterns accurately

<b>Code #6 Conclusions from data</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Accurate	0	Students' conclusions are inaccurate
	1	Some accurate and some inaccurate
	2	Students' conclusions are all accurate <ul style="list-style-type: none"> <li>○ This refers to all conclusions regardless of whether the materials explicitly ask students for a conclusion.</li> <li>○ As appropriate for the learning task</li> </ul>
Data based	0	Students' conclusion are not explicitly based in data
	1	Students conclusions are based in explicit irrelevant data
	2	Students explicitly use relevant data in their conclusions
Use of personal experience in conclusion	0	Students do not explicitly connect their conclusions to personal experiences.
	1	Students do explicitly connect their conclusions to personal experiences.

<b>Code #7 Consideration of content knowledge</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Draw on content knowledge	0	No explicit content knowledge used in data discussion
	1	Students' explicitly use content knowledge in their conclusions/data discussion <ul style="list-style-type: none"> <li>○ Students discuss explicit generalizations.</li> </ul>
Accuracy of content knowledge	0	Students' content knowledge is inaccurate or inappropriate for data discussion
	1	Students' use of content knowledge includes both accurate and inaccurate content knowledge.
	2	Students' use of content knowledge is accurate and appropriate for data discussion

<b>Code #8 Connections across investigations</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Connections to prior knowledge	0	No connections seen
	1	Connections made to investigations in the unit OR across units

<b>Code #9 Use of illustrations</b>		
<b>Criteria</b>	<b>Code</b>	<b>Description</b>
Use of examples	0	No examples given
	1	Students use inaccurate examples to clarify data
	2	Students use accurate examples to clarify data
Use of analogy	0	No analogies given.
	1	Students inaccurate analogies to describe data
	2	Students use accurate analogies to describe data or to describe how to manipulate data.