So, this is Basically the Thingy, Right? Student Sense Making in Science

Michele Hollingsworth Koomen
Gustavus Adolphus College
Hillary A. Barron
University of Minnesota
Alissa Hoffman
New Prague Middle School
Elizabeth Rodriguez
Clear Springs Elementary School

Abstract
This study explores how two middle school teachers utilized elements of scientific inquiry, including the higher sense making skills such as data analysis, interpretation, and drawing conclusions to engage their students in the processes of doing science. Using qualitative research methods, our case study situates the analysis within the macro and micro level examinations of teacher instructional activities and student discourse interactions in small groups, respectively.

Introduction

Recent reform efforts, *Next Generation Science Standards* and *A K-12 Framework for Science*, envision student experiences that mirror the practices of scientists (NGSS Lead States, 2013; NRC, 2012) and place evidenced-based reasoning at the center of student experiences in K-12 classrooms (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). One of the challenges of reform efforts is that many science teachers did not experience learning as inquiry in their own K-12 experiences (Crawford, 2007). Professional development (PD) is one way to promote experiences that mirror the practices of scientists (Koomen, Blair, Isebrand-Young, & Oberhauser, 2014; Jeanpierre, Oberhauser, & Freeman, 2005) with evidence that sound PD can lead to improvements in instructional practices and student learning (Wu & Krajcik, 2005). Additionally, we know that some of the practices of science articulated in recent reform documents are diminished in science classrooms (Koomen et al., 2014; Forbes, Biggers, & Zagori, 2013). In order to better grasp the totality of how students work through the process of "doing science" (Siry, Ziegler & Max, 2012), we must "situate the learning of science as an interactional achievement, one that encompasses the enactment of science as a culture," (p. 313). The culture of science includes the commonly attributed aspects of argumentation and evidence-based reasoning (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000), which we examine as we analyze how students form explanations. Likewise, the dynamic discourses in which scientists engage are also hallmarks of science culture, rendering student group interactions (and their related discourses) an important part of understanding how students develop sense-making of scientific concepts (Berland & Hammer, 2012). This paper explores early school year initiation into the practices of science with two science teachers and their students after the teachers completed a two-week summer professional development (PD) course. This study, guided by the following research questions, seeks to provide insight into the nature of classroom instruction following a PD and address the gap in the literature related to elusive science practices. Furthermore, as the process of doing science is "ever-moving and ever-evolving" (Siry et al., 2012), our research attempts to better understand how students navigate discourse, explanations, and sense-making in science. These attributes underscore our assertions that doing science is an emergent process and frame our analysis of students as they engage in inquiry as emerging scientists.

1. *What is the nature of classroom instruction and enactments of scientific practice early in the school year after engagement by teachers in professional development?*
2. *What is the nature of the student meaning making in response to the classroom instruction of these teachers?*

Literature Review

As researcher-practitioners, we bring together varied perspectives that ground our work in the practices of science utilizing sociocultural frameworks inherent in the making of science and conceptualize science as an emergent process.

Keywords: Sense-making, doing science, sociocultural science, discourse analysis, citizen science

Practice Based Approach to Doing of Science

We ground our research and analysis within a framework of authentic learning in science through participation in the practices of science and the construction of explanations that accompany those practices as they are enacted through instruction. *A Framework for K-12 Science Education* and the *Next-Generation Science Standards* (hereafter called the *Frameworks* and the *NGSS*) use the term "practices" to illustrate for K-12 students how professional scientists engage in science. These documents aspire to broaden our notion of what it means to do science (Table 1).

These reform efforts envision student experiences that mirror the practices and the processes of scientists (NRC, 2012) and place evidenced-based reasoning at the center of the student experiences in K-12 classrooms (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). Our PD was aligned with the recent reform documents that focus on student engagement in science as a body of knowledge, an understanding of how that knowledge is generated, and participation in the practices of science (NRC, 2000, 2007 & 2012). Our operationalized model of scientific practice guided our work with the teachers where we view scientific inquiry as an inductive and iterative process of formulating theories and validating them with evidence (Koomen et al., 2014). Additionally, we used the scientific explanations model developed by McNeil and Krajcik (2012) that include three main components:

> *claim*: a conclusion to a problem,
>
> *evidence*: data that supports the claim, and
>
> *reasoning*: a justification built from scientific principles for why the evidence supports the claim (p. 3).

Table 1. Science and Engineering Practices

***NGSS* (2013) Science and Engineering Practices**
Asking questions;
Developing and using models;
Planning and carrying out investigations;
Using mathematics, information and computer technology and computational thinking;
Analyzing and interpreting data;
Constructing explanations;
Engaging in argument from evidence; and
Obtaining evaluating and communicating information

As noted earlier, many science teachers lack a background as learners in inquiry based approaches using the explanations model (Crawford; McNeil & Krajcik). Additionally, engaging in scientific explanation, including articulating, supporting and defending explanations, is a difficult learning goal for students (Sadler, 2004). Kuhn (1991) found that constructing arguments did not come naturally for either adults or children with both subject populations had difficulty coordinating the claims and the evidence. Students have difficulty determining what is appropriate (Sandoval, 2003) and sufficient evidence to back up their claims (Sandoval & Millwood, 2005). Other researchers (Forbes, Biggers, & Zangori, 2013) found that elementary teachers using FOSS science kits enacted fewer instructional enactments where students developed explanations using evidence. Our study, following a summer PD, seeks to shed light on the ways in which seasoned science teachers enact the practices of science, including developing explanations, as a way to mediate the gap in the literature around this complex method as we answer our first research question.

Sociocultural Perspectives in Practicing Science

We conceptualize learning in science as a social process (Lave & Wenger, 1991) conducted within institutional and cultural frameworks (Lemke, 2001). Social interaction is central and necessary to learning and not merely peripheral as in the Vygotskyan tradition (Vygotsky, 1963). Science learning is therefore co-constructed as "participants 'do' science in interaction with others" (Siry et al., 2012, p. 313). As learners interact with others they co-construct meaning and draw on collective experiences, prior knowledge and cultural practices, among others (Siry et al., 2012). Therefore, emergent processes of doing science (i.e. how students begin to engage in scientific discourse, explanations, and sense-making) are socially constructed zones of proximal development (Vygotsky, 1978) by which student's speech and group interactions are examined. Pekarek-Dohler and Ziegler (2007) illustrated the ways in which scientific practices are illustrated as student's talk and interact together. In other work (Siry et al., 2012), researchers established the emergent processes that are involved as young children interact together with scientific phenomena. Our study focuses on students' group interactions and talk of middle school students who are responding to classroom instruction, an understudied area, through research question 2.

Research Design

Methodology

Our exploratory case study (Yin, 2013) featured data collection situated early in the first 6 weeks of the fall semester following the summer PD. Our data sources consisted of 15 video-taped classroom observations using the *Collaboratives for Excellence in Teacher Preparation and Classroom Observation Protocol* (CETP-COP; Lawrenz et al., 2002), field notes, interviews of the two teachers, and audio-recoding of randomly selected student interaction groups (6). Researchers took on the role of non-participant observers, where they interacted minimally within the lessons with the teachers or students.

Context. The two teachers that are featured in this study attended an NSF funded summer professional development course called *Driven to Discover: Citizen Science Inspires Classroom Investigation* (D2D2) held for the first time in the summer of 2015. The primary goal of the D2D2 PD was to utilize citizen science as a springboard to engage secondary science teachers in the practices of science. The PD was structured to introduce teachers to citizen science, provided opportunities to practice science, develop explanations in science, and focused on ways to implement this new knowledge in their classroom.

Participants. We focused this study on two teachers who completed our PD and were willing to participate in this research. Nora taught 3 sections of science in fifth grade in a rural public intermediate STEM School (grades 3-6). Lauren taught 5 sections of seventh grade life science and one section of advanced life science in a suburban public middle school (grades 6-8). Both districts were located in the Upper Midwest where the teachers had taught for more than 20 years.

Our study focused on the initiation and enactment of the practices of science, including claims, evidence, and reasoning by each teacher. Both teachers were part of the citizen science bird group in the PD, thus their instructional focus centered at the beginning of the school year on bird biology, identification, and field studies of bird populations. Nora used her adapted primary literature article (APL) developed during the PD to build understanding of the process and practice of science (Koomen, Weaver, Blair, & Oberhauser, 2016). In contrast, Lauren used the bird group field study completed within the PD to illustrate a review of existing work with her seventh-grade students to jumpstart their work in the science practices.

Data Analysis and Findings

Because our focus was both on the nature of the classroom enactments of scientific practice and the nature of student meaning making in response to said instruction, our approach to both the data collection and analysis were multilayered and multimethod. We organized our efforts into macro and micro levels that use a hybrid of analytic methods of ethnography and discourse analysis (Siry et al., 2012). To address our first research question, our macro-analysis of Nora and Lauren provided an overview of the types of instructional enactments each used to engage students, how they initiated the practices of science at the beginning of the school year, and highlight the most commonly occurring practice of science (data analysis and interpretation). To address our second research question, our micro-analysis utilized more specifically the levels of analysis within discourse (Berland & Hammer, 2012) which includes a two-pronged approach of simultaneously describing and analyzing various sections of "active developing patterns," (p. 70).

Macro Level Analysis: Nature of Classroom Instruction and Enactments

We chose the *Collaboratives for Excellence in Teacher Preparation and Classroom Observation Protocol* (CETP-COP), an NSF criterion-referenced instrument for describing and rating classroom activities in K-16 STEM schools, familiar to the authors (Koomen et al., 2014). This instrument allowed us to understand the nature of the enactments of instruction, and drill down into specific elements of scientific practice and developing explanations (see Lawrenz et al., 2002). Briefly, the instrument requires coding observed lessons across 19 different instructional practices in 5-minute increments across a lesson. The protocol calls for surveying the observed class for key indicators that reflect characteristics of reformed teaching in science and mathematics, student engagement and learning, student grouping (whole class, individual, or group work), the number of students actively engaged in the activity (3 levels: <50%, 50%-80%, >80%), and the cognitive level of the activity (4 levels: receiving knowledge, applying knowledge, representing knowledge, or constructing knowledge).

CETP/COP. Table 2 depicts the mean ratings of the CETP/COP indicators for the lessons observed. These ratings provide evidence of proficient instructional practices, with a mean score of 3.6 (±0.78 SD, scale 1-5) across all indicators. Four indicators illustrated exemplary practice (students were reflective about their learning (4.3), the instructional practices respected students prior understanding (4.4), the lessons provided strongly coherent conceptual understanding (4.1), and the teacher displayed an understanding of science concepts in her dialog with students (4.7). Additionally, the CETP-COP showed student engagement scores of 2.7 (±0.50 SD, scale 1-3) and cognitive levels of 2.2 (±0.47, scale 1-4).

Instructional strategies across the 123 five minute observational units are illustrated in Table 3. The instructional types may occur alone or in combination across

Table 2. Mean ratings of key CETP-COP indicators for lessons observed

Key Indicators of the Observed Lessons	Mean (SD)
The lesson encouraged students to seek and value alternative modes of investigation or of problem-solving	2.6 (2.1)
Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	3.0 (1.5)
Students were reflective about their learning.	4.3 (.58)
The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	4.4 (1.0)
Interaction reflected collaborative working relationships among students and between teacher and students.	3.6 (1.0)
The lesson promoted strongly coherent conceptual understanding.	4.1 (.94)
Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. (*Develop hypotheses, Analyze and Interpret*)	2.8 (1.2)
The teacher displayed an understanding of science concepts in his/her dialog with students.	4.7 (.50)
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or to real world contexts, social issues, and global concerns.	3.6 (1.3)

Note. Likert scales for each item range from 1 (not present) to 5 (occurred frequently). N = 15.

Table 3. Use of each instructional strategy across all teaching episodes

Instructional Component	Segments (%) containing instructional strategy (N = 123)
L (Lecture)	23 (19)
LWD (Lecture with discussion)	45 (37)
CD (Class discussion)	7 (6)
WW (Writing work)	13 (11)
RSW (Reading seatwork)	12 (10)
HOA (Hands-on activity)	3 (2.4)
SGD/CL (Small group discussion/cooperative learning)	38 (28)
TIS (Teacher interacting with students)	32 (26)
Other	6 (5)

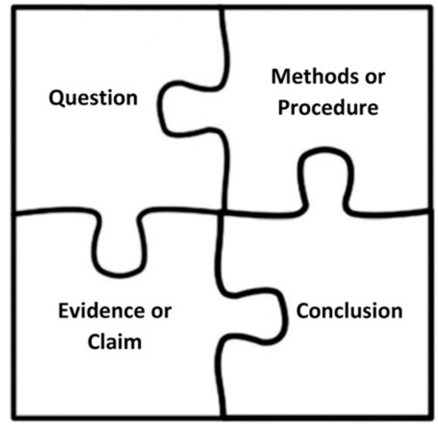


Figure 1. Puzzle Template for Question, Methods or Procedure, Evidence or Claim, and Conclusion.

the five-minute segments. Within the 15 observed lessons, two instructional strategies tended to co-occur: SGD/CL and TIS ($r^2 = 0.99$, $p < 0.0001$). When students were in small groups working on learning tasks the teacher often interacted with them.

Our secondary analysis of the instructional categories allowed us to understand inquiry enactments. Of the 123 segments 59 (48%) featured a significant inquiry component, with data analysis and interpretation garnering the most instructional time (23%) across both teachers (Table 4), a significant finding that builds from previous work (Forbes et al, 2013; Koomen et al., 2014).

Teacher initiation into the practices of science: Nora. Nora used her adapted primary literature article (APL; Appendix A) to launch "the scientific method" in the fall. Nora had the students work together in groups to identify four components of the scientific method using a puzzle template (Figure 1): the question, the method or procedure, the evidence or the claim, and the conclusion.

> Today, in your small groups, I want you to try to come up with answers to this puzzle. This article [APL] that I wrote contains all of the parts of the scientific method. We begin with the question: what does Karen Burkhart actually want to answer?
>
> Okay, now the evidence. The evidence piece is the hard one. It's what she claims she understands from doing this experiment. She measured the native [plants]; she measured the conventional [plants] at four different heights. Which one won, the native or conventional? Which one was taller, or which one had more productivity. Look at the graph. Native is taller and there is a higher percentage at 5cm, 1 meter and 15 meters, but conventional plants are more productive at 4 meters. So three out of four, would you say that's a pretty good number? Would that help her with her evidence? Do you think her evidence is really good? So when you come to claiming the part in your puzzle that says "evidence for the claim" you can talk about this chart. (*Nora, classroom observation 1)*

The underlined text above illustrates the manner in which Nora demonstrates graph comprehension and sense making (Friel, Curcio & Bright, 2001) and scaffolds the data inscriptional practices (Wu & Krajcik, 2006).

Lauren. Lauren used the field study that she completed within the PD to illustrate a review of existing work with her seventh-grade students. In the excerpts below, Lauren uses the SmartBoard to present her groups' study in a poster (Figure 2).

> I'm going to start from the beginning. I was part of this program at the University. We were practicing this process so we have a better understanding of how real science is happening. We came up with our own field studies based on a lot of observe and wonder, and a little bit of practice with little investigations. We came up with a field study question, which basically asked actually two questions, how does the time of day affect bird activity, and how does the location affect it? We also

Table 4. Number of inquiry components embedded in instructional strategies for five-minute instructional segments (59/123)

Inquiry components	# (%) of 5 minute segments
O (Observation and wondering)	1(.8)
Q (Question)	1 (.8)
HY (Hypotheses)	1(.8)
PLAN (Planning)	9 (7)
DC (Data Collection)	13 (12)
DA (Analysis and interpretation)	28 (23)
CON (Conclude)	6 (5)
Total	59

Note. Inquiry components co-occur

wanted to see if there was a relationship between those two variables. Time of day and location, in relation to bird activity.

We had four locations: an athletic field, a forest with a lot of wooded area, a park and a residential area because there are a lot of houses near campus. Our hypotheses were that we would see more at this location than these other three, and we could go through all the possibilities, right? Or the null hypotheses would be…? We did this over the course of just one day. And then we found our results. And it took us awhile to analyze these results because we had different kinds of questions we were trying to analyze. What we found was that there was more activity in the morning than in the afternoon, overall. What we also found was that they were more in the residential, more activity in the residential than the other three. *(Classroom observation, day 2)*

The underlined text excerpts above illustrate the ways that Lauren makes her own practices of science and knowledge construction apparent (Berland & Reiser, 2008). On a different observation day, Lauren went back to her study to model claims, evidence, and reasoning (CER), with the underlined text below depicting the three main components of the explanation framework (McNeil & Krajcik, 2012).

Our claim was there was a trend towards more birds in the morning. There appeared to be greater bird

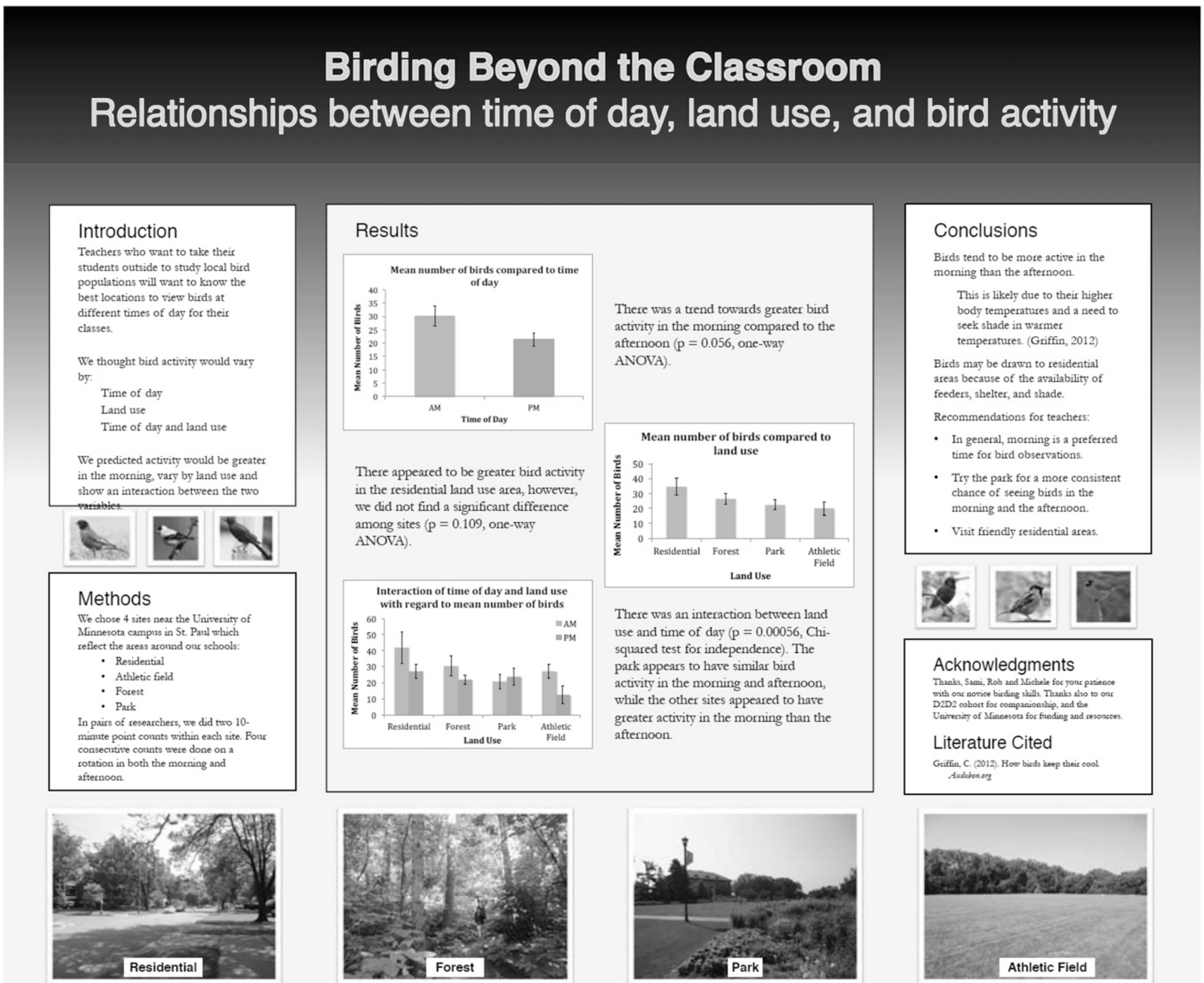


Figure 2. Field Experiment Presentation Poster by Lauren.

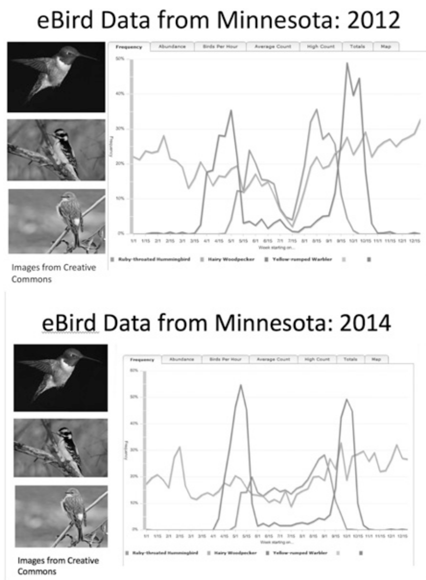


Figure 3. eBird Data for 2012 and 2014.

activity in the residential area, and there was an interaction between land use and time of day [claims]. In that case, we were talking about the fact that the park had the same amount during both times of day. For evidence, I displayed our graphs for each of these three claims. There were on average a third more birds in the a.m. than the p.m., for example 30 versus 20. There were on average a third more birds in the residential area versus the other land use areas, 30 versus 20, and the residential forest athletic fields showed more birds in the a.m., but the parks showed an equal amount in both a.m. and p.m. So, notice how this one goes to the first, this one goes to the second, this one goes to the third [evidence]. And then our reasoning, based on research, birds tend to be more active in the morning than the afternoon in the summer, most likely due to their higher body temperatures and a need to seek shade during warmer temperatures. Birds may be drawn to residential areas because of the availability of feeders, shelter and shade. And this wasn't just our opinion [reasoning]. So, claims, evidence, reasoning. *(Classroom observation, day 6)*

Data analysis and interpretation. Table 4 revealed that 23% of inquiry instructional enactments across the teachers focused on data analysis and interpretation. Nora's class decided on an investigative question related to birds (*do more birds flap their wings or glide*?) that was answered in a field study to the local college's landscape arboretum. While at the arboretum, the students, working in groups, counted the number of birds overhead that flapped or glided as they flew. Over two class sessions, Nora focused on how to build a graph from the data table with the student groups. The class saw a total of 45 birds on their field experience.

It's important to be accurate in your data on flapping and gliding, and that's your focus question. You might have to go out again and collect more data, so you have data to figure out your answer to your question. Because you want your claim to be based on evidence. The evidence is in the numbers. *(Nora classroom observation 6)*

Nora guided the fifth graders in making a graph.

Nora: Okay, try to put in that we have 30 flappers and 15 gliders. Use a ruler. Remember how the video said have space between your categories. I just wanted to ask if anybody knows, when your chart is finished, what kinds of things can you add to it yet?

Table 5. Class Time Spent in Groups

	Lauren	Nora
Group 1	17.5/55 min. (31.82%)	30/50 min. (60.0%)
Group 2	20/55 min. (36.36%)	25/50 min. (50%)
Group 3	20/55 min. (36.36%)	25/50 min. (50%)

Table 6. Average Percent Talk Moves Observed Across Both Teachers

Talk Moves	Lauren	Nora
Procedural	25.0	59.3
Knowledge Construction	41.45	34.4
Incidental	27.9	12.7

Student: The name?

Nora: I have to give it a title. Have I given my x-axis and y-axis a title? Well think about what you could call those two axes. What would you call them? What does that y-axis represent? Remember, what does it represent?

Student: Number of birds. *(Nora classroom observation, day 6)*

Like the research of Wu and Krajcik (2006) the classes spent time designing and modifying data tables into bar graphs with Nora scaffolding them throughput.

Lauren provided time for students in groups to practice analyzing line graphs from the citizen science database of eBird. The line graphs displayed frequencies across two years (2012 and 2014 (Figure 3) of three birds common in Minnesota: ruby-throated hummingbird (red-line), hairy woodpecker (green line), and yellow-rumped warbler (blue line). Student analysis was guided by a number of questions including: *What observation(s) can you make about the graphs, what question(s) do the graphs address, and what is one claim you can make when comparing the graphs?*

Last time we started work on evidence/claims/reasoning. What we are going to do is come back—there are two copies at each lab section—each copy is a graph. One is for 2014 and another for 2015. It would be helpful if you had them side-by-side so you can compare them. There are five questions. The first three questions are just looking at the graphs. Or the graphs, and answering the questions; kind of what you did with the monarchs. Not specific though; they are more open-ended. That's

Table 7. Procedural Moves: Task Clarification (Nora, Group 2)

Line	Student	Discourse Segment
328	Student 1	Okay, whose next?
329	Student 4	So, do I write down…
330	Student 2	You read the evidence. Evidence is on page 4.
331	Student 4	Draw the conclusion, no this and this.
332	Student 1	I think it's the second sentence.
333	Student 2	Yeah, then draw a conclusion about the evidence the scientist found at each place.
334	Student 1	You should do that. And she should do all of that.
335	Student 2	No, because, so yeah, technically you just draw a mini of that, just split it in half like that.
336	Student 1	So, you draw a chart and she writes down the sentence.

> what makes this one more challenging [than the others]. There is no right answer, so I want you to think hard about what you write. You can write as many claims as you can think. Evidence, of course, is what data you have. *(Classroom observation, day 10)*

In the exercise above, Leila scaffolded earlier graph interpretation (monarchs) in order to generate meaning related to CER with the two comparative graphs (Wu & Krajcik, 2006).

Micro Level Analysis: Nature of Student Meaning-Making

We narrowed our focus to zoom into the interactions of three different groups from each teacher as they worked collaboratively on tasks related to the lessons observed (Roth, 2005) to understand the nature of the meaning making of the students as they completed class activities. The discourse captured from Nora's class focused on the sense making of her teacher created APL. The discourse captured in Lauren's class related to the interpretation of the two graphs from eBird. We randomly selected three groups of students for audio recording in each classroom as students worked to develop meaning within these science activities.

Ethnographic Analysis. Like Siry, et al. (2012), we looked for basic patterns within the classroom teaching episodes. For example, in our analysis of the video-taped classroom teaching record (transcripts) and our field notes, we noted evidence for the practices of science and tried to understand how those practices were organized and understood by the teacher. We coded the transcripts using the monikers of the practices of science (Table 1) and claims, evidence, and reasoning (CER) framework.

Discourse Analysis. Gee (2014) separates notions of discourse into two main categories: "big D" and "little d" discourses. More broadly speaking, "big D" discourses are those that are characteristic of a certain way of being and include projections of people under specific circumstances. Such discourses underscore a person's "socially situated identity" (p. 47). Utterances, or language interactions that Gee identifies as "little d" discourses, have meaning in relation to the differentiated identities of socially situated people within places and activities that are likewise socially situated. We drew from the work of Jiménez-Alexandre, Rodriguez and Duschl (2000) and Radinsky, Goldman and Singer (2005) to analyze the discourse. As noted earlier, the audiotapes were transcribed and the sentences broken into units of analysis. Like Jiménez-Alexandre, et al., we analyzed the transcripts across three dimensions. First, we distinguished between components of the discourse that were procedural, knowledge construction, or incidental moves or utterances. Next, we analyzed each of the three main moves by epistemic type. For example, knowledge construction discourse included epistemic types that were reflective of sense making in scientific practices, including explanations. Finally, we calculated the percentages of talk moves.

Table 8. Procedural Moves: Task Completion (Lauren, Group 3)

Line	Student	Discourse Segment
392	Student 3	Wait so what's the answer again?
393	Student 5	This.
394	Student 3	So, this is basically the thingy, right?
395	Student 5:	She said that's the hypothesis.
396	Student 3	Can I just copy the answer?
397	Student 5	Sure.

Process of sense making in the classrooms. During their enactments, both Lauren and Nora employed small group work discussion and cooperative learning strategies where students were engaged with the material. Across both teachers, this comprised 28% of their instructional methods (Table 3). To better understand how each teacher and their students engaged in cooperative groups, we further calculated the percentage of each class time spent in this capacity (Table 5). We note that Lauren's students were in groups for about 1/3 of the class periods while Nora's students were in groups between ½ and 2/3 of the class period.

Our first analysis of the student discourse was across the three dimensions of the talk moves (procedural, knowledge construction and incidental) modeled after the work Jiménez-Alexandre et al. (2000) which is shown in Table 6. Procedural talk moves dominated the discourse of the students in Nora's classroom with a majority of those talk moves focused on understanding how to complete the task, while knowledge construction comprised the majority of Lauren's students' interactions. These talk moves for Lauren and Nora were computed as the average of procedural, knowledge construction, and incidental moves observed across their respective student groups 1, 2, and

Table 9. Knowledge Construction: Sense Making (Nora, Group 3)

Line	Student	Discourse Segment
59	Student 3	Are you sure there's no conclusion? What do you think would be the conclusion? *[pointing to the article]:*
60	Student 1	This is actually a pretty hard one
61	Student 3	I just read the last one
62	Student 1	We're starting over, just for the conclusion.
63	Student 2	It's the same pair.
64	Student 3	What's a pair?
65	Student 2	It doesn't matter about the conclusion. Results, evidence. *Look at this graph to be able to tell parts of it. Then, draw a conclusion about the plant. Scientists found that each type, with your table partner, tell how the two side – sides of the graph are giving us information. What is the information on the graph telling us? The types of plants tested.*
66	Student 4	The main percent coverage of vegetation.
67	Student 2	And then the height of each plant in each kind of plot, or each type of vegetation.
68	Student 4	It's the mean. That's what I said, the main percent of that vegetation.
69	Student 2	Well, we already figured out what it was. What is the story of this graph?
70	Student 4	What question did she ask to do the experiment?

3. Tables 7 and 8 are examples of group discourse that was procedural in nature. The focus of the excerpt in Table 7 is on two dimensions of procedural sense making: clarifying the task and who does what related to completing the puzzle components. The excerpt illustrates the multiple layers inherent as students try to figure out what they, and their group members, are to do. The focus is more on who does what versus what it means which aligns with Jiménez-Aleixandre et al.'s (2000) concept of doing the lesson. Table 8 illustrates an interaction between two group members in Lauren's class where one group member is seeking the answer (Student 3) from another (Student 5) which is another example of doing the lesson.

Table 9 and 10 are examples of knowledge construction sense making talk moves across the two teachers. While Table 9 depicts two procedural talk moves (61 and 62), the vast majority of the talk moves relate to knowledge construction or sense making. The students negotiate a conclusion or a claim with the exchanges between lines 62 and 69. We see a variety of sense-making exchanges occurring in Table 10 as the three students grapple with the analysis of the graphs. For example, Student 2 points out that the lines on the graph go up and down. Student 4 builds from that comment to reason that the amount of birds is more scattered across the year. In this exchange, the students are engaged in "doing science" rather than merely doing the lesson (Jimenez et al, 2000). They are making sense of the data.

Finally, we noted incidental moves in Table 6 at about 28% for Lauren and 13%. For Nora. Tables 11 and 12 offer examples of the incidental talk moves across the two teachers.

Discussion

This research study adds to the literature in several important ways. Our results build a case for two outcomes: Our teachers enacted many elements of reform-based instruction, including the use of scientific inquiry and developing explanations; the focus of our first research question. Our data paint a picture of the nature of classroom instruction as proficient in reformed based teaching (Table 2). Additionally, we found considerable evidence that the enactments of teaching focused on elements of scientific practices (Table 1), including about one third of those enactments focused on the higher sense making skills of data analysis, interpretation, and drawing conclusions (Table 3). Furthermore, the initiation by each teacher (Nora with the APL; Lauren with review of existing work) into the practice of science featured many examples of the

Table 10. Knowledge Construction: Sense Making (Lauren, Group 1)

Line	Student	Discourse segment
45	Student 3	So what questions does the graph address?
46	Student 1	Types of birds…
47	Student 2	Observations [*said slowly and loudly as student writes it out*].
48	Student 3	So basically, what observations does the graph answer?
49	Student 2	Ok, so you do [write]: Observation on the graph is that the lines go up and down. Which one has the highest frequency? The blue one?
50	Student 1	But even if it did have more birds, you would see it…how?
51	Student 4	The amount of birds is scattered, like, it keeps going up and down. In 2015 the amount of birds is scattered.

Table 11. Incidental Moves: Off Task (Nora, Group 3)

Line	Student	Discourse segment
70	Student 4	What question did she ask to do the experiment?
71	Student 3	How come when we say banana you think we're insulting you, when we're actually not?
72	Student 2	--right here. Nicole, if you want your job back, sign right here.
73	Student 3	How dare you! Cats--
74	Student 2	They get ran over. They get eaten by dogs. They get eaten by eagles. They get ran over.
75	Student 3	How dare you! What are you saying?
76	Student 2	I'm saying the cat slipped.
77	Student 3	How can people say that about cats? Cats are awesome. They are friendly.
78	Student 2	Dogs are better, though. They help blind people. Cats are lazy.
79	Student 3	Only some cats.

claims, evidence, and reasoning framework of McNeil and Krajcik (2012). These results begin to close the gap in the research literature regarding how teachers might foster the higher sense making skills (Forbes et al., 2013; Koomen et al., 2014).

However, when the teachers charged their students to work collaboratively on tasks on application of the skills taught, most of the nature of the discourse focused on procedural or incidental moves rather than scientific sense making (Table 6); the focus of our second research question. Of particular importance was the amount of time students spent in groups in comparison to the amount of sense-making and knowledge constructing processes that happened during cooperative group interaction. For example, while Nora's students spent more time in student-to-student interactions, they reflected less knowledge construction. In contrast, Lauren's students engaged more frequently in knowledge construction even though the amount of class time spent in groups was less. This low level of engagement is articulated in the systematic review of small group discussions carried out by Bennett, Hogarth, Lubben, Campbell and Robinson (2010), in which they found that purposeful and structured group work is critical in science learning. We did not document any class sessions related to training students around the nuances of effectively working together in groups or staying on task, an outcome that may have contributed to less than 50% sense making discourse across both teachers (Table 6), yet, studies document the importance of such training programs (Bennett et al.; Howe, 2014). Furthermore, Bennett et al., advise care in the composition of student groups, including gender and behavioral characteristics with evidence from one study documenting that friendship groups of single sex function more effectively and develop deeper understanding (Hogan, 1999).

Additionally, our outcomes build from the work of Siry et al., (2012) and Jiménez-Aleixandre et al. (2000). Expanding on their work, we found that "doing science" encompasses more than sense-making alone, it includes procedural and incidental moves that co-occur as students practice science (Table 6). Thus, in our exploratory case study, we found that it is an intermingling of "doing science" and "doing the lesson" with more students' engaging in incidental or procedural talk moves versus sense making (Table 6). As noted above, each of the teachers broached CER within their initiation into the practices of science with their students (Table 4).

Table 12. Incidental Moves: Off Task (Lauren, Group 3)

Line	Student	Discourse segment
364	Student 5	Can I copy that.
365	Student 1	I feel dumb, yeah sure. I feel dumb.
366	Student 3	Cause you are.
367	Student 1	I'm not dumb.
368	Student 3	If you weren't you would be done with your packet. He was in front of the camera for like 5 minutes.
369	Student 1	That's okay I get on TV a bunch of times.
370	Student 3	What?
371	Student 1	My dad does play by play for the Gophers so whenever they see me on the sidelines or something they'll put the camera on me.
364	Student 5	Can I copy that.
365	Student 1	I feel dumb, yeah sure. I feel dumb.

Conclusion and Implications

Teachers might implement elements of a PD in their classrooms, however, that does not mean that these methods trickle down to the students. Greater monitoring of students as they work in groups is important. Much of the work on small group discourse analysis focus on the use of lab equipment and mastery of experimentation versus sense making of students related to natural phenomena (Howe, 2014), an implication of our work for future research. Sense making is a key component if students are to develop a deep level of content understanding that goes beyond the superficial level inherent in "doing the lesson" (Berland & Reiser, 2008). Our research also points to the importance of a teacher giving effective directions about what the students are to do. Effective directions seem to be imperative if students are to get past the "doing the lesson" versus doing science (Jiménez-Aleixandre, et al., 2000).

As the process of science is "ever-moving, ever-evolving" (Siry et al., 2012, p. 314) so must be our approach in educational research. As we continue to learn about the contexts, characteristics, and interactions that students navigate as they engage in scientific sense-making, it is critical that we work with teachers (informally in PDs and through teacher preparation programs) to mirror key elements of scientific literacy so their students can move beyond doing the assignment and into the realm of doing science. In doing so, teachers and students alike can be empowered to use these skills to solve real world problems. Finally, and as noted above, overall more time was used for procedural and incidental tasks, with less overall time spent on scientific sense making. As we continue to conceptualize science as a sociocultural endeavor, we need to begin to understand how we might optimize sense making in small group discourse knowing that parts of said discourse will focus on incidental and procedural moves. Further research might explore what is an optimal proportion of different talks moves (i.e. procedural, incidental, knowledge construction) if the goal is sense making.

References

Bennett, J., Hogarth, S., Lubben, F., Campbell, B., & Robinson, A. (2010). Talking science: The research evidence on the use of small group discussions in science teaching. *International Journal of Science Education*, *32*(1), 69-95.

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching*, *49*(1), 68-94.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, *93*(1), 26-55.

Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain. *Educational Researcher, 33*(8), 3-15.

Barton, A. C., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls.

Crawford, B. (2007). Learning to teach science as inquiry in the rough and rumble of practice. *Journal of Research in Science Teaching, 37*(9), 613–642.

Fogleman, J., McNeill, K. L., & Krajcik, J. (2011). Examining the effect of teachers' adaptations of a middle school science inquiry-oriented curriculum unit on student learning. *Journal of Research in Science Teaching*, *48*(2), 149-169.

Forbes, C. T., Biggers, M., & Zagori, L. (2013). Investigating essential characteristics of scientific practices in elementary science learning environments: The practices of science observation protocol (P-SOP). *School Science and Mathematics, 113*(4), 180-190.

Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in mathematics Education*, 124-158.

Gee, J. P. (2014). *An introduction to discourse analysis: Theory and method*, 4th edition. New York: Routledge.

Goodall Jr, H. L. (2000). *Writing the new ethnography*. AltaMira Press.

Hogan K (1999) Thinking aloud together: a test of an intervention to foster students' collaborative scientific reasoning. Journal of Research in Science Teaching 36: 1085-1109.

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effects change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching, 42*, 668–690.

Jiménez-Aleixandre, M. P., Rodriguez, A. B., & Duschl, R. A. (2000). " Doing the lesson" or" doing science": Argument in high school genetics. *Science Education*, *84*(6), 757-792.

Koomen, M. H., Blair, R., Young-Isebrand, E., & Oberhauser, K. S. (2014). Science Professional Development with Teachers: Nurturing the Scientist Within. *Electronic Journal of Science Education*, *18*(6).

Koomen, M. H., Weaver, S. Blair, R., & Oberhauser, K. S. (2016). Disciplinary Literacy in the Science Classroom: Using Adaptive Primary Literature. *Journal of Research in Science Teaching,* 53(6), pp. 847-894.

Kuhn, D. (1991). *The skills of argument*. Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Lawrenz, F., Huffman, D., Appeldoorn, K., & Sun, T. (2002). *Classroom observation handbook,* University of Minnesota, Minneapolis, MN, 2001.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of research in science teaching*, *38*(3), 296-316.

McNeill, K. L., & Krajcik, J. (2012). Supporting grade 5–8 students in constructing explanations in science: The claim, evidence and reasoning framework for talk and writing. Boston, MA: Pearson.

NGSS Lead States. 2013. *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

National Research Council. (2012). *A Framework for K-12 Science education: practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Oliveira, A. W., & Sadler, T. D. (2008). Interactive patterns and conceptual convergence during student collaborations in science. *Journal of Research in Science Teaching*, *45*(5), 634-658.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of research in science teaching*, *40*(7), 692-720.

Roth, W. M. (2005). *Doing qualitative research: Praxis of method* (Vol. 3). Sense Pub.

Siry, C., Ziegler, G., & Max, C. (2012). "Doing science" through discourse-in-interaction: Young children's science investigations at the early childhood level. *Science Education*, *96*(2), 311-326.

Vygotsky, L. S. (1978). Mind in society: The development of higher mental process.

Windschitl, M. (2002). The reproduction of cultural models of inquiry by pre-service teachers: An examination of thought and action. *Proceedings of the International Conference of the Learning Sciences*, 2002.

Wu, H. K., & Krajcik, J. S. (2006). Inscriptional practices in two inquiry-based classrooms: A case study of seventh graders' use of data tables and graphs. *Journal of Research in Science Teaching*, *43*(1), 63-95.

Yin, R. K. (2013). *Case study research: Design and methods*. Sage publications.

Acknowledgements The authors would like to thank the journal editors and the anonymous reviewers who provided valuable feedback on earlier versions of this article. We are grateful for the enthusiastic assistance of undergraduate researchers Kameryn Schaefer and Greta Ferguson. This work was supported by a grant from the National Science Foundation (DR K-12-1417777). Any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the position or endorsement of the funding agency.

Author contact information:
Michele Hollingsworth Koomen,
mkoomen@gustavus.edu;
Hillary A. Barron,
fult0050@umn.edu;
Alissa Hoffman,
alhoffman@isd721.org;
Elizabeth Rodriguez,
Elizabeth.rodriguez@minnetonkaschools.org

Appendix A

APL Product for Nora, Author of "How do native plants affect birds and butterflies in city landscapes?" (An adapted interpretation of Burghardt, K.T., Tallamy, D. W., and Gregory Shriver, (2009) Impact of Native Plants on Bird and Butterfly Biodiversity in Suburban Landscapes. Conservation Biology, 23(1), 219-224.)

SCIENCE BEHIND THE SCENES
ADAPTED PRIMARY LITERATURE

INTRODUCTION

How do scientists get started?
Scientists are looking for ways to understand how changes made in our backyard landscapes have affected plants and animals. In this unit we will study how humans interact with the natural world. The best place to start in understanding this is to look at experiments that have been done by scientists in this field of study called ecology. These experiments are called primary sources. A primary source means that we are using the final published version of the actual experiment. Let's look at this primary source which used the scientific method.

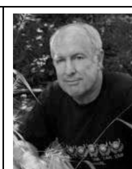
One summer, some scientists decided to try to figure out if planting non-native and ornamental rather than just native plants would affect some city landscapes. They decided to do a science experiment that tested how it changed other organisms too. They studied city properties that had only native plants and compared them with those that had non-native and conventional plants. They also studied caterpillars to find out if it affected the caterpillars, and the birds that ate them.

Fig. 1 californianativeflor .com

Fig. 2 landscapingnetwork.com

REFLECTION........How can we connect these three? The plants, the birds, and the caterpillars? What did we study earlier that helps us?

Meet the Scientists who did the experiment.

 KARIN T. BURGHARDT - Karin is the main experimenter. She is a researcher at Yale University and is currently studying meadow management and insect disturbances. She teaches in the department of Ecology and Evolutionary Biology at Yale.	 DOUGLAS W. TALLAMY - Douglas has made the case for using native plants in every landscape, no matter how small, and believes that planting these natives in small landscapes will create biodiversity to support what's left of our wildlife. Professor Tallamy is chairman of the department of Wildlife Ecology at the University of Delaware.	 W. GREGORY SHRIVER - Gregory is a professor of wildlife ecology and researcher at the University of Delaware. He is also building a research program focused birds and bird ecology and conservation biology.

Glossary

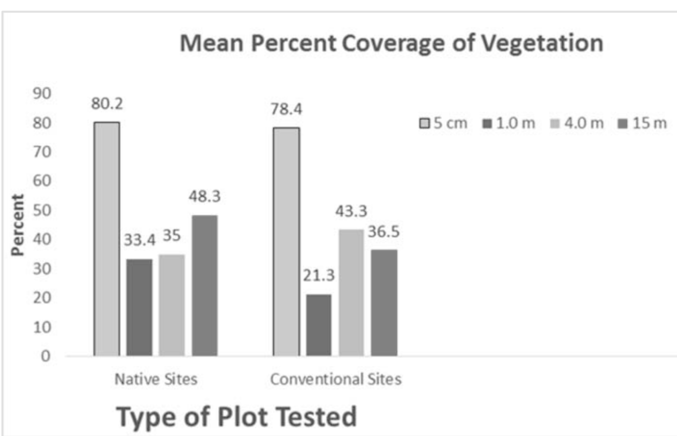
Biomass - the measure of how productive soil is
Biodiversity - many varieties of life
Native – naturally occurring in that region
Conventional – the usual
Birds – food limited species and native to this study area
Non-native plants – plants not usually present in an ecosystem
Ecosystem*
Energy Pyramid*
Food Chain *
Review these words - recall what these three words mean with your science buddy.

METHODS

Karin, Douglas and Gregory had to find a place in southeastern Pennsylvania to do their experiment. They used six pairs of city properties (12 total). One of each of the pairs was completely planted with native plants. The other one of the pairs was planted with a mix of more conventional plants.

They used four different heights when taking samplings - 5 cm, 1m, 4m and 15 m. The data they collected gave them evidence which helped them get evidence while using the scientific method. They looked at how the plants changed the biomass in the soil. The study lasted from June 2006 to August 2006.

REFLECTION.........What pieces of the scientific methods you have used this year do you recognize in this section right now? How did she decide what to include?



Pair and share about the inquiry skills we have practiced this year so far....the bird sightings experiment, tongue rolling/widow's peak study, and plant experiment. How is this experiment like the ones you have done and how is it different? What claims can we make about the chart in Fig. 3?

RESULTS: HER EVIDENCE

Look at this graph and be able to tell the parts of it. Then draw a conclusion about the plant coverage scientists found at each height.

With your elbow partner, tell how the two side-by-side sections of the graph are giving us information?

REFLECTION....... What is the story of this graph? How are the set of bars on the left (Native) like the set of bars on the right (Conventional)? Write an "I wonder" statement in your journal about the graph and the story it tells.

DISCUSSION

The diversity of the native plants positively affected the abundance (food supply) of the caterpillars which meant that the birds also had more food. On the native plants, the caterpillars were four times more plentiful. The city plots with a greater percent of different types of native plants were a greater source of energy in this food pyramid. Did this data (evidence) answer the original question? How do native plants affect birds and butterflies in city landscapes?

REFLECTION......... Now that you know more about how planting some native plants can change the outcome for birds and butterflies, think of your own choices. Would you plant the typical plants in your backyard or would you use native plants? Why? Plan to debate this for a few minutes when we finish.

FACTIVITY......... Now that you have used a scientific primary source to learn more about how scientists study issues of land use.....Use the space below to graph one of the groups of yards (plots) - Native or Conventional that you see on the graph (Fig. 3). Discuss with an elbow partner what you will include and what each part of your graph represents. How will your graph tell the story of the research these scientists did?

CLASSROOM APPLICATION......... In my classroom, I have many levels of accomplishment to work with. I would use this writing to help my lower level students with both reading skills and with graph interpretation. Because it also has components of review, it would be used to review the contents learned earlier in Ecosystems and Energy and to develop graphing skills.