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High School Biology in the Age of the Next Generation Science Standards: A Student-Centered Approach

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Abstract: The article describes a biology teacher's approach to inquiry-based instruction grounded in a sociocultural learning perspective. The course designed by the Biology Teacher includes references to the literature and epistemic practice-based routines and procedures. The urban students in this study integrate the practices to design an investigation to solve a problem with soil quality. Specific details describe the epistemic practices enacted by the students and their responses to the learning experience. The study illustrates how the Biology Teacher used the students' culture, experiences and knowledge to promote meaningful science practice related to the lives of the students. The study was conducted in an urban environment; however, approaches are conducive to science instruction in all NGSS classrooms.

Introduction

Reform in science education has occurred in response to increasing demands for citizens who can solve practical health, political and social problems using science (Feinstein, Allen, & Jenkins, 2013). Beginning in the 1980s the demands for a scientific literate populous focused on preparing students to become science majors for colleges and universities, building student confidence, and developing students' appreciation for the usefulness of science. Since then, there has been a push toward instructional practices that facilitate science knowledge and skills. The National Research Council (2012) calls attention to scientific unifying concepts and processes to accomplish this goal. Numerous studies in recent years support replacing the cookbook style procedures of science of the past with more inquiry-based learning (Weaver, 1998, Hart et.al, 2000). Inquiry-based instruction is an important science teaching strategy that involves supporting students in investigating questions and using data as evidence to answer questions (Caps & Crawford, 2013). Moreover, inquiry-based instruction provides a context to begin learning about the nature of scientific knowledge (Schwartz et.al. 2004).

The Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Idea, encourages teachers to emphasize the integration of core science concepts and has operationalized inquiry into eight science and engineering practices. The core concepts and practices are intended to be taught together in a coherent learning experience where students can make meaningful connections between and among direct experiences with science and engineering practices and language arts skills including reading, writing, speaking and listening (Pearson, Moje, Greenleaf, 2010).

This approach to science teaching has shown promise with improving academic achievement of students, particularly female and minority students (Gormally, Brickman, Hallar and Armstrong, 2009; Lamoureux, Beheshti, Cole, and Abuhimed, 2014). Unfortunately, many urban students have limited experiences with inquiry-based instruction and this is partly due to teacher preparation and quality (Anderson, 2007). As of 2012, 69% of science teachers in affluent schools had advanced degree verses 49% in schools characterized by students living at the poverty line (National Science Board, *Science and Engineering Indicators*). In addition, advanced secondary school courses, such as physics and calculus, are offered at lower rates in schools that serve African American and Latino students.

The focus of this study was to determine how one urban biology teacher in Southern California attempted to offer high quality, inquiry-based science instruction to urban African American and Latino students. Specifically, this paper examines one teacher's approach to using inquiry-based instruction and a sociocultural perspective of learning to create a student centered approach for improving science academic achievement.

Theoretical Framework for NGSS

Informed by the previous work on inquiry-based science instruction and what is known of typical school science learning experiences, two science practices were designed for urban students to engage in inquiry-- *Text Study and the Know, Question, Hypotheses, Learned (KQHL).* The practices provide students access to science learning by combining aspects of sociocultural learning theory as articulated by Hollins (2011) and by negotiating epistemologies as described by Sandoval (2004). By combining Hollins focused inquiry and directed observation, with Sandoval's concept of epistemologies needed for science learning, three principles for science academic achievement were enacted in this study: 1) student-centered science instruction, 2) student apprenticeship in biology, and 3) explicit teachings in scientific methodology.

The first two principles, *student-centered science instruction and student apprenticeship in biology,* allowed students to use their experiences and social and cultural tools to make sense of science and engineering practices (Hollins, 2008; Brown and Ryoo, 2008; Rivet and Krajcik, 2007). Participating in an apprenticeship in biology means that students learn professional practices (at a developmentally appropriate levels) by using knowledge and skills together in a specific context. Students ask questions, use tools of science, learn professional norms for solving scientific problems and engage in the same habits of mind of scientists (Hollins, 2011; Wu & Wu, 2010; Lehre, Schauble & Lucus, 2008).

The theoretical construct underlying the student centered approach is also related to Hollins (2012) student centered, teaching and learning. This construct is based on research conducted in an urban school setting that addressed student English language arts achievement. When students' attributes such as their culture, language and community were recognized and integrated into the instructional delivery, student performance increased. Examples given were the Algebra Project (Moses, Kamii, Swap, and Howard, 1989) were student learning was built upon students' learning preferences and strengths derived from their cultural and experiential backgrounds; and the Foxfire Approach (Wigginton, 1977), where Appalachian students were encouraged to link their community interest to language arts, as a result academic achievement improved by allow students to engage as historians and journalists for documenting their Appalachian culture. These instructional mechanisms provided students opportunities to actively participate in their learning and also provided voice to student ideas, concerns and questions in an affirmative manner. In the current study, the teacher grounded the learning in community based problems that were meaningful to their lives. Students were allowed to use their own problem solving approaches while integrating the routines and processes of the discipline for science learning.

In considering how to ground urban science teaching with the Hollins' student-centered approach, we recognized that urban students have not had exposure to consistent quality or frequency of inquiry-based learning opportunities, and have experienced cookie-cutter versions of the scientific method (Kahle, Meece, and Scanthebury, 2000). The biology instructor in this study sought to address this problem by representing investigation and science text negotiation as processes students could easily use when prompted to do so in science problems or tasks. Science problems and tasks were constructed to reflect students' interests, values, prior knowledge and experiences. These contextualized problems and tasks attempted to link students' prior knowledge and experiences to science and engineering practices. Problems and tasks integrated with personal experience were used to anchor learning for units and lesson plans. The focus was to create a series of meaningful coherent learning experiences anchored by scenarios that would prompt students to engage in science and engineering practices in meaningful ways.

The third principle is teaching explicitly about the diversity of scientific methodologies (Sandoval, 2007). Introducing inquiry as a series of methodologies that facilitate the ability to distinguish ideas from experimental design, to test ideas, to use evidence to support claims and to communicate information that improves students' scientific decision making (Chinn, Betina, & Malhotra, 2001). Students who are given explicit instruction and support for engaging different methodologies develop epistemologies that are aligned with the discipline. These epistemic practices are processes and routines, grounded in the discipline norms of the science profession, used to teach content over time. Because the literature indicates that students, specifically urban students, do not experience quality inquiry-based instruction (Junlei, L., David, K., & Siler, S., 2006; Rudolph, 2005), the teacher in this study used epistemic practices to involve students in explicitly discussing prior knowledge regarding ideas, linking evidence to claims, the testability of hypotheses, and the collection, organization and analysis of data. In addition, the teacher wanted students to make connections between different forms of science methods and how forms are iterative and integrated depending on the context of the scenario. For example, students identified and described methods presented in a text and were prompted to think about how they could modify the method to test their own hypotheses. Students were also taught to use the text to support or reject claims made from student-derived evidence. The goal was to understand the function of each science methodology (investigation and science text negotiation) and to understand how forms used together help construct scientific knowledge, understanding and skills. Epistemic practices, used as science and engineering routines helped guide students through the complex way of knowing and doing, and to improve science academic achievement.

Making sense of how to engage urban students in inquiry-based learning to improve academic achievement was the emphasis of the study. Considerations included the idea that urban students construct their school experiences using social and cultural tools from their homes and the community. Using cultural/social tools and epistemic practices in authentic ways support deep and durable student involvement in science. Hollins (2011) described a sociocultural apprenticeship approach to learning how to teach that involved two interrelated teaching experiences, *focused inquiry,* and *directed observation*. *Focused inquiry* into a practice allows students to use tools and clarify any gaps in understanding. *Directed observation* is the purposeful attention to a particular skill demonstrated by a skillful practitioner. Together, these two processes support academic achievement.

Hollins' approach to learning how to teach was applied to the contextualization of the epistemic practices in this study. Engaging in the epistemic practices was viewed as an apprenticeship where students were provided with culturally appropriate science scenarios or activities that prompted them to read a text, plan an investigation, observe a phenomenon, or attend to a demonstration. These anchoring activities segued into subsequent learning experiences that provided support, to engage in epistemic practices and for students to answer essential lesson level questions. At the end of the unit, students were expected to explain the anchoring phenomenon, answer the lesson level essential questions, overall unit driving questions, and to present arguments.

The study tracked growth of two biology students' understanding of seedling growth as they learned content using epistemic practices. The interest was both in the students' developing understanding of inquiry-based reasoning and their understanding of collective problem-solving. Biology is a domain that requires students to deploy and coordinate extended chains of reasoning that entail complex forms of causality (Grotzer & Basca, 2003; Leach Driver, Scott, & Wood-Robinson, 1996). Typically, high school students are capable of coordinating the relations that constitute inquiry-based learning, such as cause and effect and energy and matter, and can sustain self-regulated inquiry in this domain (Eilam, 2002). However, the students in this study have experienced limited inquiry-based learning experiences over extended periods of time. Therefore, this study is a suitable test/analysis for investigation of the prospective effects of sustained systematic inquiry-based instruction.

Research Question

Given our theoretical position, this study sought to explore the primary question: What effect does teaching epistemic practices through the use of *focused inquiry* and d*irected observation* have on student science learning? The findings from this study will help design science classroom activities that support students' understandings of how scientific knowledge is constructed through inquiry.

Methods

Setting

This study was conducted at a Southern California Urban High School. Southern California Urban High School (SCUHS) is a 9th -12th grade comprehensive school in Los Angeles, CA with an average population of 2216 student. Historically the school consisted of a majority of African American students (over 80%), the study population has stabilized in recent years to 55% African American and 45% Latino. The Latino population primarily come from Mexico, with a significant percentage from a variety of Central American countries. Over 80% of students participate in the free or reduced lunch program.

Participants

One hundred and sixteen 9th and 10th grade students from five biology courses participated in the study (n = 64 girls and 52 boys; average age 15 years). The students had a range of academic abilities and many of the students were designated English Language Learners. Ms. Smith, who had been teaching biology in high schools for more than 12 years, taught all classes. Ms. Smith received a B.S. degree in biology and held a master's degree in school psychology and a Doctorate in Education. Ms. Smith has actively participated in inquiry-based professional development activities characterized by instructors modeling instructional strategies, providing resources, kits, and recent scientific information from the literature regarding the shift in science teaching that the NGSS represents.

Design

Two participants were selected from the population of 9th/10th grade biology students to describe the inquiry-based learning experiences of the study. The two students represented proficient and development levels of performance using the epistemic practices. Ms. Smith was the classroom teacher, responsible for instruction and introduced *focused inquiry,* and *directed observation* in her instructional approach.

Activities

The challenge for this research was to identify ways to coordinate certain aspects of inquiry-based learning that were aligned with students' development, and represented three dimension inquiry found in the *Framework for K-12 Science Education*. The coordination tools developed by Ms. Smith were designed to make the processes of investigation and negotiation of text accessible for students and teach the professional norms of the subject matter. These coordinated processes were delivered through Ms. Smith's epistemic practices.

Epistemic Practices

Although investigation and the negotiation text are activities commonly found in science classrooms, these activities usually direct students in a step-by-step fashion leading to known answers and results (National Research Council, 2008). The intent is probably to make inquiry "student-proof" because teachers feel uncomfortable negotiating student failure. At the same time, this recipe-like approach is a distortion of scientific practice (Lehre, 2008). In contrast, students are expected to learn to ask questions, build and revise systems for investigation, invent measures, construct data representations that are convincing to other investigators, and decide what conclusions are warranted and how much trust they should be given (National Research Council, 2007). To coordinate these activities, Ms. Smith designed two epistemic practices, the text-study and *KQHL*. Each activity involved multiple science and engineering practices recommended by the national science framework such as asking question, designing investigations, and communicating findings. Because students had limited prior experience in inquiry-based learning, it was difficult at first for students to engage in tasks without the teacher's guidance. To help students learn, Ms. Smith provided scaffolds and guidance through clarifying and facilitative questions, demonstrations, one-on-one interaction and by the use of strategic small groups.

The text-study epistemic practice included (a) requirements for developing research questions to guide inquiry into the different types of text students were exposed to (textbook, laboratory protocols, supplemental science readings), (b) a list of research methods, (c) examples of data sources and (d) instructions on how to write the; data analysis; findings; and summary of a science text. The findings portion of the text-study consisted of the answers to the research questions that students were required to write at the beginning of the process. During the focused inquiry, students were encouraged to use their socio-cultural background and past everyday science experiences to make sense of the tools (question frames, rubrics, data sources, and research methods lists). It was stressed that this process will not change as the year progresses, only the content of the process changed. Using this format the urban students were expected to acquire important prerequisite skills for science literacy development. Allowing the students to express their knowledge, in their own way, granted them access to learning science content.

For the investigation of the epistemic practice, students were asked to share what they know about a topic, pursue their own questions, and engage in planning and implementing investigations based on what they know. The investigative process was supported by using a scaffold that mirrors the *text-study,* the *KQHL*. The *KQHL* is likened to the KWL but there are significant changes. First, students work together in research groups where they highlight any background knowledge needed to identify aspects of the topic that can be measured. Then, students consolidate this information under the "K" section, much like the "K" section of a KWL. Second, students use the same question frames from the text-study process to construct 5 research questions (Q) that can be used to create an hypotheses, or what the students want to learn about. The hypotheses are possible answers to a research question and are testable (H). Next, students set up their laboratory activity to test their hypothesis, collect their data and then organized the data for analysis. Students were then able to make claims about what they know from the laboratory experience and support what they know using components of the *text-study*. The claims were written under the "L" section of the *KQHL,* indicating what they learned. Finally, students were able to support or reject their hypotheses based on the analysis of the data and the support of their claims. When students were introduced to this process they examined (a) the instructions on how to share their experiences with their peers in the "K" section, (b) guidelines for constructing five questions about the laboratory topic, (c) how to choose a question from the previous step to formulate a hypothesis in the "if…then" statement format, (d) how to collect, organize and analyze data, (e) how to use data to support or reject a hypothesis, and (f) how to construct an argument by using information from the data analysis and supporting textual information from the text-study. This process was conducted for every laboratory activity.

The emphasis on text and investigation was intended to ensure that scientific reasoning and knowledge would be addressed in a coordinated manner. However, it was clear that employing the shift required to implement inquiry-based instruction, required shifting how science is taught. Hence, Ms. Smith initiated two forms of activities designed to realize a viable culture of scientific inquiry. She used *focused inquiry* and *directed observation* to teach and support the two epistemic practices.

Focused Inquiry

Ms. Smith solicited students' questions, curiosities and discourse about the concepts and big ideas and coordinated discussions through epistemic practices. During *focused inquiry,* students examined: 1) the rubrics for the text-study and *KQHL*; 2) examined scaffolds that organized the processes of the practices; 3) completed student work from past courses; 4) the components of each practice; and 5) the relationship between epistemic practices (i.e. how similar the methods in the text are to the methods used for planning investigations). The elements of the practices are linked to students' prior academic and social experiences with science.

Questions posed during *focused inquiry* such as, "Do we copy the subheadings of the text?"; and "How many questions do we need to ask in order to move on to the hypothesis?" represent the students' concern with procedures for completing the assignments and receiving a "good grade." Questions and discussions later in the year illustrated students' focus on inventing measures, refining protocols to test hypotheses, and organizing and analyzing data. *Focused inquiry* was considered fruitful if discussions lead to students helping each other understand science concepts and protocols ("We are looking at cell division this week and it looks like we are using microscopes again") and if they resulted in empowering students to be self-regulatory ("We are engaged in a lab for this topic so we have to first discuss what we know and then pay attention the text this week to get ideas about how to investigate it").

Students' judgements about research questions, hypotheses, methodologies, were accompanied by similar discussions to identify, collect data and for analysis. These processes were coordinated in the text-study and *KQHL* routines and used across learning experience. Students eventually were able to initiate and engage in these processes on their own.

Directed Observation

The second activity used to operationalize inquiry was *direct observation.* During *direct observation*, students observed Ms. Smith demonstrate practices used to learn content. Students attended to: a) decision about when to choose a particular practice; b) knowledge needed to engage in the practices; c) scaffolds used to coordinate the practices; d) how the practices inform each other; and e) how to use the practices to make claims based on evidence. Students were prompted to discuss how they would use the text-study and *KQHL* to learn a concept. Directed observation was dominated by student-to-student and student-to-teacher discourse characterized by definitive statements, clarifying questions, cueing by teachers and peers, potential hypotheses and plans for testing hypotheses. For example, a team of students were taking inventory of the equipment needed to test their hypotheses concerning cells. As an approach, they proposed to use the microscope to determine the relative size of the cells, select a particular stain to see the cells, and reviewed the function and structure of the cells. However, as students discussed their plan, Ms. Smith interjected in regards to which tools were appropriate for certain types of testing as demonstrated in the following discussion:

> Ms. Smith: O.K. I've now demonstrated the basic protocol for investigating cells this week. What types of questions do you think I can ask about cells?
> Tyrone: You can ask whether or not the cells can move or not.
> Elizabeth: I don't know if you can do that, where are you going to get the cells?
> David: Hold up, I'm still trying to think of questions...I think that you can use the microscope to see the cells move so I'm going to ask a question about that.
> Ms. Smith: So, what I'm hearing is that I can test whether or not I can see cells
> move. What was the overarching question are we looking at this week ("How does cell structure determine function")? And is that connected to the mobility of the cells?
> Elizabeth: No. it is not connected to the question this week?
> Ms. Smith: Are you sure? Where can we find information that can help us formulate good questions?
> Elizabeth: You told us to go back to the text study
> Ms. Smith: Right, where else can you go?
> David: The textbook or the websites that you recommended…
> Ms. Smith: Where on the KQHL do I record the questions we are creating?

Students were attending to the connection between methodologies for studying cells and the types of questions that could be investigated. The discussions served to clarify how the epistemic practices were used to learn the content and to increase student awareness of the epistemological relationship between questions, testing, and types of data collected.

One purpose for engaging students in *focused inquiry* and *directed observation* was to make inquiry-based instruction accessible to high school students without “watering” down the material. The opportunities for learning is positioned within a constructivist-sociocultural perspective with an emphasis on sharing experiences with fellow students, questioning, and engaging in science and engineering practices with careful guidance. The emphasis on accessible inquiry was atypical of urban high school science, and thus the practice was aimed at students’ science learning. By using *focused inquiry* and *directed observation* to deliver instruction, students were able to learn the epistemic practices first (*focused inquiry*) and then use them as skills to construct knowledge (*directed observation*). We also wanted to know more about how students reasoned about biology while using epistemic practices, to respond to the questions; What was the scope of their understanding? Would it be narrowly focused on the procedures of the epistemic practices or would student discourse and writing provide evidence of scientific reasoning and improved academic skills?

In summary, two teaching components addressed the following themes:

1. *focused inquiry:* What was the nature of the questions students asked when epistemic practices were used to teach? What aspects of the epistemic practice did students find easy to understand? Which aspects were difficult?
2. *Directed Observation:* What demonstrations, teacher questions, strategies or approaches increased accessibility for students when learning with the epistemic practices? What decreased accessibility?

Data Analysis

The analysis was guided by the text-study and *KQHL* assignments. The first step was to identify two students, one successful at using the epistemic practices across learning experiences, and one who struggled and improved over time. Students were rated as proficient, or developing with their understanding of the nature of the epistemic practices (e.g., what they are and what information is needed to use them) and the function of epistemic practices (e.g., how epistemic practices are used in the course and what is learned from using them). For the nature of epistemic practices, the student scoring proficient (>74/100) described the text-study and *KQHL* as processes that help coordinate science practices and concepts, interconnected (e.g. methods in the text inform how to refine laboratory protocols to test hypotheses on the *KQHL*), and used to develop claims supported with evidence. The student rated as developing (scores between 59-74/100) indicated that the epistemic practices are assignments completed in the science course and represent the scientific method. Developing students have difficulties making connections between the practices or using the tools to actively investigate a big idea in science.

For the function of epistemic practices, ratings for proficient (>74/100) indicated that students could use scientific text to develop ideas about science, infer investigative methods, identify potential data sources, express common sense theories on science topics and plan and carry out investigations. The students rated as developing (scores between 59-74/100) had difficulties negotiating text and engaging in investigation. For the text study, students may focus on extraneous features of the text or not attend to key components such as figures, diagrams and graphs depicting laboratory procedures, models of phenomenon, or the relationship between subheadings. For investigation, students may have trouble making testable hypotheses or refining laboratory procedures to test predictions.

Focus Inquiry into the Epistemic Practices

From the *focus inquiry* data, students' questions and clarifying statements about how the practices were represented, how the practices' interrelatedness is made explicit, and how the practices support constructing knowledge were rated as "complex," or "superficial." The questions and statements in the "complex" category contained inquiry about procedures, concepts, and justifications for a particular text or investigation. The student questions and statements in the "superficial" category contained questions about procedures or concepts, but not both. These individuals did not attend to multiple usages of the epistemic practices, their questions or statements grouped in the "little/none" category were characterized by questions or statements not related to the epistemic practices, and had very few indicators of the learning expectations.

Directed Observation of the Epistemic Practices

Directed observation was focused on eliciting student responses as they attended to certain aspects of the practices in action. Direct observation can be described as: The Teacher demonstrates the practices as students direct the "moves" of the teacher. Students are provided with prompts to make decisions about the logical progression through the practices while the teacher modifies demonstrations, uses examples and analogies, and constructs questions to help students make sense of the practice. The aim was to observe patterns in the elicited responses from students concerning the use of epistemic practices. Student responses to teacher prompts were coded into groups of skills described and cross-referenced with the type of knowledge reported to support the description. The tables below illustrate the description.

Skills	**Indicators**
Science Investigation	Asking questions, hypothesizing, Designing experiments, observing, measuring, and interpreting data
Text-Study	Writing and speaking scientific terms in complex sentences, asking questions, identifying scientific methodologies, identifying how text is organized, and using scientific information to support or reject claims

Knowledge	**Indicators**
Science Investigation	Knowledge of the phenomenon, Knowledge of controlled experiments, Criteria by which scientific knowledge is evaluated

Text-Study	Knowledge of scientific representations (models, diagrams, formulas), knowledge for judging scientific claims, knowledge of context in which science is used

Findings

To illustrate the range of student performance, we first summarized the responses from a proficient as described above. As mentioned, one student demonstrated the ability to use the epistemic practice to coordinate the processes of inquiry and one student initially had difficulties with coordinating the processes.

Proficient Student

We begin with the student that successfully used the epistemic practices to learn biology. Students were introduced to a learning experience grounded in the following scenario:

> A group of farmers are experiencing decreased crop production and need direction to solving the problem. You are scientists who are tasked with developing an investigation into soil quality and seedling growth. Your job is to investigate ways in which farmers can improve their soil composition and increase crop production.

We start the first discussion with a proficient student who used the two epistemic practices to approach the scenario: Asia

Focused Inquiry

Coordinating the six components of the text study was a major challenge during the initial *focused inquiry* into the text-study activity. To figure out how to use the practice, Asia first reviewed the sample of student work given by Ms. Smith. Each section was clearly labeled and Asia began to ask questions about how to initiate the process, “Ok, I start off with questions but how do I know what questions to ask?” She noticed that she could use the question stems document that was provided by the instructor to create questions. For the methods section of the text-study, Asia reviewed the “practice-text” for figures, pictures, and diagrams. She noticed that figures included pictures of animals, plants, and some included equipment or tools. Asia pointed out that scientists take pictures of the world, and that this may help them make better observations. She then made the connection between what she noticed in the practice text to what was expected of her in the course, “I’m going to do what these scientists did, make observations, take pictures maybe?” When prompted by Ms. Smith, she attempted to make sense of how text was organized using the headings of each section, “It states here that when you are doing science we use the metric system, then we use the system to organize data, to use microscopes when we work with cells. Can I put that down as the data analysis?”

For the *KQHL,* Asia appeared to have difficulty understanding how to alter the laboratory protocol to test a student-created question or hypothesis. For example, growing pea plants was the practice investigation to introduce the *KQHL* epistemic practice. The protocol called for growing seeds in sand or soil, however, Asia and her team decided to investigate how light affected seedling growth: “There are no instructions in the protocol for how we can test sunlight...how are we going to set up the lab?” After being reassured by Ms. Smith that space and equipment was available to set up a light vs. no light experiment, the team decided that the variable was darkness, and that they could use the cabinets under the laboratory sinks as a “dark growing place” and put a separate group of seedlings under the growing lights.

Directed Observation

The purpose of directed observation was to elicit student responses about a phenomenon and to facilitate the use of the epistemic practice to learn the content and to increase the accessibility of science. For the initial directed observation of the text-study, Ms. Smith posed the question, “What questions can we come up with to help us understand the tools and procedures of science?” she challenged students to develop five questions about the section of the practice text. Each student had a copy of the practice text and was encouraged to brainstorm questions in small groups and then share them with Ms. Smith who made them public for the entire class. Asia actively referenced the question stems as she worked with her peers. She also reminded her peers that they could use the question stems: “I’m going to go with how many different types of tools are used in science?” Once Asia and her peers developed five questions they selected one person to share out one of their questions. Ms. Smith then wrote the question under the document camera and added it to a growing list of questions the class created.

Asia and her team then began to evaluate the figures and diagrams in the section of the text. Asia discussed with her elbow partner that the pictures in one figure have magnification labels, and each picture is 400x, 2200x, and 1000x respectively. Ms. Smith explained that figures, diagrams and graphs all have clues as to what methods were used to collect data that informed the reading. Asia determined for the magnification figures, there must have been a camera that took the pictures and magnified the organisms in them. Ms. Smith used the information to address the class and asked, “Is there another type of tool that can magnify and take pictures?” Another students provided a response, “Microscopes.” Asia heard the response and stated: “Oh, that was obvious, it says right here in the book, light microscopes and electron microscopes.” Ms. Smith and the class completed the text study by identifying possible data sources (i.e. pollen grains, bacteria, and plants), discussed how information was organized in the text (i.e. measuring systems, data analysis and tools), and the activity ended with responses to the student questions created at the beginning of the process and with a written summary that explained the topic of the section.

Developing Student

Like Asia, Rodney also experienced some difficulties with using the epistemic practices to engage in inquiry.

Focused Inquiry

During *Focused inquiry,* Rodney could recognize the components of the text-study and follow the accompanying rubric to understand what was required when writing his own questions and provide examples using the question stems. For example, Rodney used the lower level Bloom’s portion of the stems resulting in questions such as “Which shows the order of the metric system?” and “How would you compare light microscopes to electron microscopes?” As Rodney moved to the methods section of the text study, he began to have difficulties understanding what was required to link methodologies to the topic, “I’m not sure what to do here.” “What does it mean by methods?” Ms. Smith explained that he was to infer from the diagrams, pictures, figures and graphs what the scientists were doing or had done in order to present the information in the section. Despite these instructions, Rodney found it hard to determine the meanings of the figures and diagrams. After reading a section of text that included micrographs of pollen to explain how microscopes are used in biology, he reasoned that the micrographs demonstrated how "scientists used pollen grains to measure in biology." He did not understand that scientists were using microscopes as tools for observing pollen grains. Ms. Smith addressed this challenge in two ways, one she used an analogy to make Rodney's implicit logic public to him and shared a list of science tools and their function. When working one-on-one with Rodney she stated, "What you are basically saying is your face is used to reflect images. Is that true?" Rodney perplexed, answered "No." "What do you use to reflect images or what do you use to see yourself?" Ms. Smith asked, " OK., just like how you know that a reflection is done by a mirror, I want you to know that small objects, smaller than you can see are magnified by a microscope."

When Ms. Smith shared the list of tools, she instructed Rodney to link the tools in diagrams and figures to their function on the list. For example, Ms. Smith pointed out that if he sees micrographs or pictures with magnifications that these pictures indicate that scientists used microscopes to see items that cannot be seen with the naked eye. This is what she means by "inferring." The text does not always tell you exactly what scientists have done but they give you clues. She then instructed him to write his inferences in the methodology section of the text-study.

During *focused inquiry* into investigation, Rodney was better prepared to participate in discussion and understand the process of asking questions, developing hypotheses, and telling what he learned. He followed the logic of his table mates and went along with the class consensus about which questions were tested and the methods students in previous years used to perform the tests. During table conversations Rodney rarely referenced the rubric when discussing the examples of student work. Ms. Smith came over and asked "Why do you think this student chose to use microscopes in this protocol?" Rodney answered "the students needed the tool to see objects that were too small for the naked eye." It took more probing by Ms. Smith to help him make the connection that cells were small and the students needed to use microscopes to see them.

Directed Instruction

During *directed observation*, Rodney found it difficult to work with his peers when guiding Ms. Smith's demonstration on how to engage in the text-study. One problem that arose was Rodney's habit of focusing on parts of text that were not pertinent to identifying methodologies, data sources or data analysis. He stated that he continuously searched for figures and pictures to inform him of what to write in the methodology, data sources and data analysis sections. Ms. Smith did not deter Rodney from doing this, but instead informed him that if he is looking at the figures and diagrams, he should "skim the text to find where they discuss the figure, and how this may give you clues as to where in the text-study this information belongs." Ms. Smith then gave the whole class time to engage in this activity (about 3 minutes) and returned the whole class to the overhead for conversation. This is where she called on Rodney to share what he found in the text with his peers. As he shared what he read and how it informed what he thought about methodologies, data sources and data analysis, Ms. Smith actively wrote his responses on the overhead, making sure to organize his responses under the appropriate headings.

Much like Asia, there was some difficulty with alternating the laboratory protocol in order to test hypotheses. Rodney insisted on not changing the protocol, "Why can't I just do the experiment that the protocol says?" Ms. Smith informed him that the questions he and his group created could not be tested by the given protocol and that the protocol would need modification. Ms. Smith worked with this group directly, helping them brainstorm through their research questions, "Can seedlings grow in Gatorade?" She began her interaction with the students by asking them "How can you test whether or not seedlings grow in Gatorade?" Rodney stated that he and his team could “grow one seed in Gatorade and another seed just using water..” They were then probed by Ms. Smith to determine if they needed to do anything else for the investigation. She encouraged the group to discuss control variables, the manipulated variable, and what they were going to measure as a dependent variable. Rodney stated that he expected to measure the length of the plant as it started to grow, and remembered that he would be measuring with the metric side of the ruler.

Summary and Conclusions

The biology teacher in this study intended for students to develop questioning skills, critical thinking, and to work towards developing a community of learners in the classroom. Classroom communities and learning are as diverse and complex as the student bodies that they are comprised of. Taking a sociocultural stance to learning biology requires that teachers need to learn a great deal about their students and the communities in which their students reside in order to provide for and support authentic learning opportunities. This study presents a perspective of science learning that is counter to the “conventional wisdom” of science instruction where students engage in activities in order to receive the transmitted information in the format of an “elite” class. In contrast this study presented an epistemology of systematized and operationalized methods of encouraging students to participate in inquiry and interrogate expository text in real ways the students could relate to. In this type of classroom, the teacher intentionally critiqued her cultural script, shared it with her students, and asked for student input in the scope and sequence of the learning activities. In order to do this, the teacher needed an inquiry-based approach that included student voice and thought. The approach included the planning, enacting, interpretation and translation of student learning outcomes in response to the planned learning events. The use of *focused inquiry* and *directed observatio*n teaching as epistemic practices for instruction created the foundation for an inquiry-based approach to teaching and learning.

The student dialogues progressed from a focus on the procedures of the text-study and investigation process to seeking assistance with the content of hypotheses, the connections between the methods of the text-study to the procedures for the laboratory activities, and seeking approval for modifying laboratory procedures and using data to support or reject hypothesis.

The findings from this study suggest that the use of epistemic practices for teaching learning processes has a positive effect on urban high school biology student academic performance. The actions of the teacher required a commitment of time in order to address student interaction, participation and learning through the use of *focused inquiry and direct observation*. The *focused inquiry* component of instruction required the teacher to plan an investigation and transform it into a process that provided coherence and continuity between topics and units. Directed observation required the teacher to provide guidance during student investigations in order to assist them in making connections between the discipline core and the cross-cutting concepts, which also provided an opportunity for guided practice processes. The teacher actions increased the confidence of the students and encouraged collaboration. In addition, the Hollins approach as an instructional strategy provided students with an opportunity to actively participate in their learning and provided voice to student ideas, concerns and questions in a positive affirmative manner. For many students the teacher took the role of facilitator and elder in the room, indicating that the process has potential for empowering students to direct their own learning. Monitoring student performance on the products of epistemic practices, based on a student centered approach, is one indication that the students’ participation in focus inquiry, directed observation and guided practice has potential for supporting positive learning outcomes in the era of NGSS.

References

Anderson, D. R. (2007). *Model Based Inference in the Life Sciences: A Primer on Evidence* Fort Collins: Springer.

Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A “content-first” approach to science teaching. *Journal of Research in Science Teaching, 45*(5), 529-553. doi:10.1002/tea.20255

Camangian, P. (2010). Starting with Self: Teaching Autoethnography to Foster Critically Caring Literacies. Research in the Teaching of English, 45(2), 179-204.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-Based Instruction and Teaching About Nature of Science: Are They Happening? *Journal of Science Teacher Education, 24*(3), 497-526.

Eilam, B. (2002). Strata of comprehending ecology: Looking through the prism of feeding relations. *Science Education, 86*(5), 645-671.

Feinstein, N., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. Science, 340, 314-319.

Grotzer, T. A., & Basca, B. B. (2003). How does grasping the underlying causal structures of ecosystems impact students' understanding? *Journal of Biological Education, 38*(1), 16-29.

Hart, C., Mulhall, P, Berry, A., Loughran, J. . (2000). What is the Purpose of this Experiment? Or Can Students Learn Something from Doing Experiments? . *Journal of Research in Science Teaching, 37*(7), 655-675.

Hollins, E.R. (2008). Culture in school learning: Revealing the deep meaning. New York: Routledge Publishers.

Hollins, E.R. (2011a). Teacher preparation for quality teaching. Journal of Teacher Education 62(4), 40.

Hollins, E. R. (2011c). The meaning of culture in learning to teach: The power of socialization and identity formation. In Ball, A. F. & Tyson, C. A. (Editors.), Studying Diversity in Teacher Education. New York: Rowan & Littlefield Publishers.

Hollins, E. R. (2012). Learning to teach in urban schools-The transition from preparation to practice. New York: Routledge Publishers.

Junlei, L., David, K., & Siler, S. (2006). What Lies Beneath the Science Achievement Gap: The Challenges of Aligning Science Instruction With Standards and Tests. *Science Educator, 15*(1), 1-12.

Kahle, B., Meece, J., & Scantlebury, K. (2000). Urban African-American middle school science students: Does standards-based teaching make a difference? *Journal of Research in Science Teaching, 37*(9), 1019-1041.

Leach, J., Driver, R., Scott, P., & Wood-Robinson, C. (1996). Children's ideas about ecology 2: ideas found in children aged 5-16 about the cycling of matter. *International Journal of Science Education, 18*(1), 19-34.

Lehrer, R., Schauble, L., & Lucas, D. (2008). Supporting development of the epistemology of inquiry. *Cognitive Development, 23*(4), 512-529.

Moje, E. B. (2007). Chapter 1 Developing socially just subject-matter instruction: A review of the literature on disciplinary literacy teaching. Review of Research in Education, 31, 1-44.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual Framework for New

K-12 Science Education Standards. Board on Science Education. Washington, DC: The National Academies Press.

National Science Board. (2000). Science and engineering indicators 2000 (NSB-00-1). U.S. Government Printing Office, Washington, DC

Pellegrino, J. (2013). Proficiency in science: Assessment challenges and opportunities. Science, 340, 320-323.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and Science: Each in the Service of the Other. *Science, 328*(5977), 459-463.

Rivet, E. & Krajcik, S. (2008). Contextualizing instruction: Leveraging students' prior *Research in Science Teaching, 45*(1), 79-100.

Rudolph, L. (2005). Inquiry, instrumentalism, and the public understanding of science. *Science Education, 89*(5), 803-821.

Sandoval, W. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*(4), 634-656.

Southerland, S., Smith, L., Sowell, S., & Kittleson, J. (2007). Chapter 2: Resisting Unlearning: Understanding Science Education's Response to the United States' National Accountability Movement. Review of Research in Education, 31(1), 45-77.

Weaver, C.G. (1998). Strategies in K-12 science instruction to promote conceptual change. *Science Education, 82*(4), 455-472.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. Review of Educational Research, 72(2), 44.

Wu, HK. & Wu, CL. . (2010). Exploring the Development of Fifth Graders' Practical Epistemologies and Explanation Skills in Inquiry-Based Learning Classrooms. *Research in Science Education, 41*(3), 319.