ISSUES IN INQUIRY-BASED SCIENCE EDUCATION SEEN THROUGH
DEWEY'S THEORY OF INQUIRY

BY

MIHYE WON

DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Secondary & Continuing Education
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2009

Urbana, Illinois

Doctoral Committee:

    Professor Bertram C. Bruce, Chair
    Professor Marilyn Johnston-Parsons
    Associate Professor Fouad Abd-El-Khalick
    Assistant Professor Barbara Hug

Abstract

To understand the issues of inquiry-based education, I adopted John Dewey's theory of inquiry as the analytical framework to examine science learning activities, students' interactions, and education standards. Educators have tried to engage students in meaningful learning, but the analysis revealed that the meaning of inquiry was diverse: interesting hands-on materials to teach scientific knowledge; collaborative group work for independence and democratic attitudes; and dynamic problem solving to change the community and the students' identities. Efforts to connect students' experiences with school learning aimed at different learning outcomes and consequently met with a different set of dilemmas in drawing students' participation and supporting their learning. The interaction among the educational goals, the learning outcomes, and the difficulties shows that we need to evaluate carefully the meanings of inquiry-based education and its learning goals in order to find better ways to ensure students' growth to its fullest.

Acknowledgements

In the long journey of my graduate study, I have met many wonderful people. They provided generous support for my intellectual growth and for this dissertation. I'm afraid I cannot fully acknowledge all the people I'm indebted to, but I'd like to express my gratitude to some of them here.

Bertram (Chip) Bruce gently guided my inquiry through the doctoral study. He always saw the best in me and led me to find alternative perspectives and seek deeper questions. His continuous encouragement along with financial supports made this dissertation possible. Marilyn Johnston-Parsons provided generous help and guided me to navigate Deweyan theory. Barbara Hug and Fouad Abd-El-Khalick shared their perspectives on issues in science education and urged me to connect with the science education community. Cynthia Carter Ching provided constructive comments for my analysis, even after she moved to California. Margery Osborne, David Brown, Arlette Willis, Rochelle Gutierrez, Jennifer Greene, and many other faculty members at the College of Education offered their prestigious perspectives on various educational issues and helped me shape this study in its early stages.

Kevin and Laura, teachers at a local middle school, kindly welcomed me into their classroom and helped me to see both the promise and the issues of inquiry-based science education in current school settings. I am grateful to both of them. Lisa Bouillion and Michelle Torrise also kindly shared with me their research experiences, insights, and resources regarding the cases of the study. When I stumbled as I was teaching undergraduate courses, Sarah Lubienski's sympathetic ears and kind words helped me regain the joys of teaching. Mr. Milton, despite his illness, tirelessly helped me with ESL lessons. When I catch myself saying 'inquiry' with an exaggerated lip movement, I know it's all because of his effort.

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Chapter 1

Dewey and Inquiry-Based Education

Dewey in Contemporary Science Education Studies

Many contemporary science educators highlight the role of inquiry in learning science and try to implement inquiry-based education. When they argue that students should have an opportunity to participate in scientific inquiry in school, they refer to John Dewey as a pioneer of inquiry-based science education. The National Research Council (NRC) notes Dewey's view of science as "a way of thinking and an attitude of mind" (NRC, 2000, p. 14) rather than just a body of knowledge. Dewey's understanding of science is often quoted as a rationale of inquiry-based education as follows:

> Dewey's general theme was that science teaching gave too much emphasis to the accumulation of information and not enough to science as a method of thinking and an attitude of mind: "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter." (Dewey, 1910/1976, p. 70) (requoted from Bybee, 2000, p. 25)

Dewey very much valued the scientific way of thinking as a tool to bring change and liberate people from prejudice (Connell, 1994). He realized that an open attitude, rigorous experimentation, and critical reflections of scientific inquiry make its knowledge claims powerful. He thought the scientific habit of mind fosters invaluable characteristics, such as open-mindedness toward alternative approaches, confidence to move forward with effort, and responsibility for the consequences of one's action (Connell, 1994). Because of the critical role of scientific thinking in conducting a fruitful inquiry, he regarded science as a useful heuristic to make an inquiry more trustworthy and successful. Dewey (1910/1976) thus insisted on the

importance of teaching a scientific way of thinking in schools as both a subject matter and as a general method for learning.

> The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit. (Dewey, 1910/1976, p. 78)

Although Dewey's emphasis on teaching scientific thinking has been cited in the science education literature, both the details of his theory of inquiry and the full implications of his general educational theory have remained peripheral to much of science education research and practice. Some people believe his work is outdated; others think it has been examined and understood well enough already. However, many Deweyan scholars have challenged such beliefs.

Despite frequent references to Dewey, contemporary educators are introduced only to bits and pieces of his theory without comprehensive background knowledge (Rodgers, 2002). Dewey wrote a vast amount of writing throughout his life, with each work emphasizing different aspects of education. Without a complete understanding of his theory, people may draw an understanding that is quite different from his life's work (Johnston, 2002). As a result of limited access to his theory, contemporary educators often end up implementing an educational practice at odds with his educational vision, while attempting to embody what they conceive as his ideas (Tanner, 1997).

For example, the *National Science Education Standards* (NSES) and other science education literature frequently refer to "*Science as Subject-Matter and as Method"* for Dewey's work. In that piece, Dewey emphasized his hopeful regard for scientific thinking. He regarded the scientific method as a general guideline for inquiry and not necessarily technical in nature (Connell, 1994), yet many people often take his emphasis on scientific thinking as if he argued

for teaching the mechanical steps of the scientific method to improve student's inquiry ability

(Tanner, 1988). This interpretation is a distortion of his theory. Dewey (1938/1991) repeatedly

emphasized the fluidity of inquiry problems, the situated nature of inquiry, and inquiry as a

participatory practical action. Without mentioning those contextual components of inquiry, his

praise of the scientific method is well known in contemporary science education literature, yet

his theory is incorrectly interpreted as positivistic (Schubert, 1980). Deweyan scholars consider

that interpretation to be ironic, "since Dewey opposed positivism from the start" (Garrison,

1997, p. 98). Because of this misinterpretation, Tanner (1988) asserted, "There is a striking

difference between Dewey's view of [inquiry[1]] and the views of those who are responding to the

call to put more [inquiry] in the curriculum" (p. 471). Rodgers (2002) regretted that such practice

leads not only to more isolation of Dewey's theory from the education field, but also limits our

understanding of the possibilities and issues of inquiry-based teaching and learning. Dewey's

theory demands a more careful examination in order to be productively incorporated in current

contexts.

This critique of the widespread interpretations of Dewey raises several interesting

questions: What did Dewey really mean by inquiry and by engaging students in inquiry activities

for learning? How would a better understanding of Dewey make his theory more relevant to

science education today? To what extent does it provide an analytical framework for science

learning activities in school? How does it offer a new perspective for evaluating inquiry-based

teaching and learning? What are the most valuable contributions of his theory in addressing

contemporary issues?

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[1] While examining Dewey's idea, Tanner (1988) used inquiry interchangeably with critical thinking in the
text. I thus changed 'critical thinking' to 'inquiry' in the quote.

In order to answer those questions, I bring Dewey's theory of inquiry in dialogue to three prominent educational topics: (a) education standards for inquiry-based education, (b) students' nonparticipation in school activities, and (c) social implications of school learning. The full educational implications of Dewey's theory are yet to be realized, but this study afforded me an opportunity to reflect on the meaning of inquiry and the pedagogical goals of our education as well as to consider the inquiry-based education that Dewey envisioned.

Overview of the Study

In Chapter 2, I describe my understanding of Dewey's theory of inquiry. Inquiry ranked as one of Dewey's main ideas in his career as an educational philosopher, and there are various interpretations (Johnston, 2006). Rather than delving into the multiple meanings or debates around Dewey, I describe my understanding of Dewey's theory of inquiry, which has guided this research. I believe my interpretation is useful not only for understanding the meaning of inquiry-based teaching and learning, but also for addressing issues of inquiry-based education to build better possibilities.

Adopting Dewey's theory of inquiry as an analytical framework, I examine issues of science education in various contexts in the following chapters. I intentionally chose a wide variety of sizes and settings, ranging from a national education standard document to students' conversational interactions in class, to several science projects comprised of a series of activities, to a historical interdisciplinary curriculum from Dewey's Chicago Laboratory School. I have provided some background information on each context for readers before engaging with Dewey and educational issues.

Among the most frequently mentioned words in contemporary educational discourse is "standards." Regardless of whether one is critical or enthusiastic about these standards, they

provide a convenient reference point for contemporary educational ideas. *The National Science Education Standards* (NRC, 1996, 2000) provides a set of goals for inquiry-based science teaching. An analysis of this document in Chapter 3 allows us to evaluate some common assumptions about inquiry-based science education.

In Chapter 4, I move to a micro-analysis of students' interactions to examine what kinds of inquiries students are actually engaged in during a science learning activity. The interactions occurred at a local middle school called Prairie Middle School, where I conducted a year-long observation study. A video analysis of three student groups illustrates the dynamics of social, emotional, and intellectual interactions in relation to the academic task.

In Chapter 5, I investigate how the teachers implemented inquiry at the Chicago Laboratory School, which Dewey founded. It was challenging to comprehend a teaching practice that occurred 100 years ago, but I couldn't omit this case because the school was directed by John Dewey himself and closely related to his theory development. From various historical documents, it was clear that the school achieved remarkable success in building productive learning environments. Yet, I also realized that the teachers were facing issues similar to those of their contemporary counterparts and could not fully embody the social aspect of the inquiry-based education Dewey envisioned.

In Chapters 6 and 7, I explore a couple of community-based school activities. In contrast to typical science learning activities, students participated in planning and executing a series of community actions to improve the quality of their lives. The activities at Whittier Elementary School and Pedro Albizu Campos Alternative High School were chosen to consider a broader, alternative possibility for inquiry-based learning projects in school.

In Chapter 8, I discusse what we can draw from the dialogues between Dewey's theory of inquiry and various issues evident in inquiry-based science education.

Chapter 2

Dewey's Theory of Inquiry for Inquiry-Based Education

Dewey was a prominent educational philosopher who believed philosophy must contribute to enhance human lives, and thus focused on the concerns and questions from ordinary lived experiences (Boisvert, 1998). His assiduous effort to draw fuller meanings from our experiences resulted in a unique, comprehensive perspective that resonates with our times. Among Dewey's many writings, *Logic: The Theory of Inquiry* (1938/1991) integrates his view on experience, knowledge, society, and of course inquiry. It provides an alternative, valuable insight on the goals and issues of contemporary inquiry-based education.

In this chapter, I describe my interpretation of Dewey's theory of inquiry, drawn from some of his most celebrated work [e.g., *The Child and the Curriculum* (1902/1976a), *The School and Society* (1900/1976), *Democracy and Education* (1916/1980), *Experience and Education* (1938/1988), and *Logic: The Theory of Inquiry* (1938/1991)] and selected works by Deweyan scholars (e.g., Boisvert, 1998; T. Burke, 1994; Campbell, 1995; Connell, 1994; Garrison, 2001; Johnston, 2006; Tanner, 1997). I then relate some key aspects of his theory to draw educational implications for inquiry-based education by introducing a set of analytical components.

Dewey's Theory of Inquiry

Dewey defined the meaning of inquiry in *Logic: Theory of Inquiry* as follows: "Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituents distinctions and relations as to convert the elements of the original situation into a unified whole" (Dewey, 1938/1991, p. 108). This definition is not easy to grasp without both a general understanding his philosophy and some key words used in the definition, such as controlled transformation, indeterminate situation, and unified whole. Before delving

into Dewey's theory of inquiry, it is beneficial to understand his ecological, participatory understanding of the world.

Viewing the world in relation to our interactions. Dewey considered society as an ecosystem, in which human beings are dynamically interacting with their surroundings (Noddings, 2007). The simple act of eating, for example, is an interaction with the environment. Our way of eating is influenced by the amount and type of food, the occasion, the location, the custom, and other environmental elements. By eating the food, we satisfy our hunger, delight the chef, and leave less for others. Thus, our activities involve dynamic, harmonious interactions with the environment.

Because of such constant interactions, Dewey observed that the environment is an integral part of our lives and it is functionally related to us (Garrison, 1998). He (1935/1987) wrote, "Life goes on in an environment; not merely in it but because of it, through interaction with it…The career and destiny of a living being are bound up with its interchanges with its environment, not externally but in the most intimate way" (p. 19). The reciprocal interaction with environing social and physical conditions was the fundamental quality of living beings for Dewey. He (1935/1987) described such interchange with environments as "the very process of living" (p. 42).

Observing the intimate functional relationship of living beings with the environment, Dewey (1916/1980) viewed what constitutes an experience is not passive reception of data from the world, as many philosophers have perceived. Rather, to Dewey, active participation is the core of having an experience. "When we experience something, we act upon it, we do something with it, and then we suffer and undergo the consequences" (p. 146). Because Dewey considered experience to be such a dynamic interaction within our environments, he thought that through experience, we come to reconstruct ourselves and the environments (Talisse, 2002). Dewey

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(1938/1988) wrote, "Experience does not go on simply inside a person. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had" (p. 22).

In contrast to Dewey's thinking, we have traditionally believed that the truth is 'out there' to be discovered by us, and what we experience does not necessarily reflect the world as it really is. Because of the discrepancy between our experience and the truth according to Cartesian dualism and Platonic idealism, we need to distrust our experiences, remove ourselves from any predisposition and contemplate the world in order to represent the world correctly. Such epistemology of remote knowledge is the base of our education, and we strive to teach students the objective body of knowledge, in contrast to students' experience-based or need-based situational knowledge (Harkavy & Benson, 1998).

Dewey resisted pursuing *the* real meaning of the world. He observed the world as continuously evolving in relation to human beings, and it can be understood differently depending on the objectives. Instead of explaining our knowing in terms of subject (spectator-knower) and object (to be known), Dewey explained the mechanism in terms of inquirer, objective, and subject-matter, in which inquirers seek to acquire relevant information of the context in relation to the experiences (Boisvert, 1998). This implies that knowing is derived from our interaction with environment, and the world can only be understood by our active participation (Connell, 1994).

Because of such reasoning, it is not only meaningless trying to represent the world away from our experiences but also impossible to understand the world separately from our interactions within it. Dewey believed that in order to understand the world, we need to purposefully engage in the world as active participants, rather than contemplating the remote world. Here, knowing is not an absolute truth, but a provisional, probabilistic guide to make our

future action intelligent and improve the world in return (Boisvert, 1998). Thus, the main criterion of knowledge to Dewey is how much it contributes to making progress in our lives. Dewey's transactive perspective on the world, experiences, and knowing is integrated in his theory of inquiry.

Inquiry as the way to live and learn. As a particular kind of experience, Dewey recognized inquiry in relation to the life-long process of learning and interacting within environments (Talisse, 2002). As we continuously interact within environments, the changing world brings various challenges to our usual ways of interacting. When a challenge disrupts our usual coordinated interactions, we recognize the situation as problematic and initiate a process to change it into a well-balanced interactive system so that we can resume our life. In the transformative process, we get to know our environment and ourselves better. Such transformation and sense-making process is called inquiry (Dewey, 1938/1991).

Because we interact with the world in countless ways and encounter challenges at various points of our lives, Dewey (1938/1991) wrote, "[Inquiries] enter into every area of life and into every aspect of every area" (p. 106). He thought doing inquiry is "at the very heart of what it means to be human. It is what enables us to make sense of and attribute value to the events of our lives" (Rodgers, 2002, p. 848).

When we say "inquiry" within contemporary education discourse, we often think of a certain kind of school-based teaching method—one involving hands-on, open-ended, student-centered, reform-based, problem-solving activity in the form of collaborative group work. To Dewey, however, inquiry is not just a part of academic work. It is the way people live and learn throughout life, not one of the many teaching methods for teachers to consider (Bruce, personal communication, 2005). The difference between the common conception of inquiry and Dewey's inquiry becomes clear once we consider inquiry in a boring lecture hall.

Imagine in a big lecture hall, the professor is reading a textbook in monotone about the evolution of ancient animals and half the students are either dozing off or text-messaging under the table. Contemporary educators would disappointedly say that inquiry is definitely not happening in this class. Most students are not engaged with the professor's lecture. There is neither a hands-on activity, nor any other form of activity that would engage students. In contrast, Dewey would be able to see some kinds of inquiry going on in such a class. Some students may be testing their patience and the ability to find valuable links from the presented information to answer their own questions. For some others, they may be building their 'crap detecting' ability (Postman & Weingartner, 1969) and listing why not to take this course. The students who are dozing off may be pushing the boundaries of what they can do in class and trying to reconstruct their role—from passive listeners to active saboteurs of the course. This, however, is not the kind of inquiry that educators hope to see in an academic setting. Indeed, schooling is to guide students' productive inquiry, not to replenish their sleep (Dewey, 1916/1980, 1938/1988). Yet, to Dewey, any of those students' behaviors could be an act of inquiry.

We frequently link inquiry with achieving the academic goals set by the teacher. If students are not following the teacher's direction to achieve the academic goal, they are not engaged in an inquiry: they are just uninterested or uninvolved. On the other hand, Dewey would include those delinquent behaviors as a form of inquiry. Inquiry is our natural effort to resolve a problematic situation and to build understanding of our environment and ourselves. Those students are actively trying to address their own agenda in the given circumstances. Thus, regardless of the alignment with the teacher's set goals, students are engaged in an inquiry as long as we are intentionally and reflectively performing an action to address a situation.

Also apparent in the above scenario is the difference in the scope of inquiry between Dewey and contemporary educators. We often limit inquiry to a cognitive aspect. If students are

engaged academically in the material, students are doing an inquiry. If students are engaged in the material for its social or emotional aspects (e.g., building social relations with other classmates), they are not exactly doing an inquiry. On the other hand, Dewey included all aspects of human activities as inquiry because he viewed inquiry as part of our life. Our life does not bring just cognitive challenges. We are tangled in a complex web of emotional, moral, social, and physical components. Our inquiry inevitably addresses various aspects of our lives.

Dewey's broad conceptualization of inquiry may perplex contemporary educators. If inquiry is everyday sense making and students are already doing inquiry on their own accord, why do we need to teach it to students? If students' inquiry takes place regardless of the teacher's instruction, does it mean we should leave the students to do whatever they fancy? If inquiry involves noncognitive aspects, what are the boundaries of academic learning? What is the main goal of inquiry-based instruction, anyway? To answer those questions, we first need to examine what initiates inquiry in relation to Dewey's continuity of experience.

Construction of a problematic situation in the continuum of experiences. In order to initiate an inquiry, an inquirer needs to see that a situation indeed requires an inquiry (Dewey, 1938/1991). The construction of a problematic situation is not a simple mechanism of stimulus-response, but the result of interplay between the lived experiences of an inquirer and the environment as a whole. I explore below what constitutes a problematic situation and its educational implications. The unconventional way of thinking about the interaction between the situation and lived experiences will provide an insight for how to prepare a productive learning environment for our students.

Situation as a contextual whole. Dewey's view on a problematic situation illustrates his ecological understanding of the world—as an interconnected and interdependent environment (Boisvert, 1998). When we face a problematic situation, we tend to isolate an event or object as

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the cause of a problem. Yet, our responses are not simply inscribed in and controlled by an object or an event. Rather, they are the results of the complex interplay of our experiences and various environmental elements.

This point is well explained in Dewey's critique of the reflex arc concept of psychology (Dewey, 1896/1972a). A stimulus in psychology is understood to evoke a certain response, which is independent from previous experiences or the context (Hickman, 2001). For example, if a young girl sees a candle on a table and puts her finger into the flame, a candle is the stimulus and putting the finger into the flame is the response. There is no contextual or experiential explanation given in this stimulus-response model. Dewey noticed such a simple model overemphasizes certain aspects and doesn't tell the whole story because a candle in itself cannot inscribe the response. If we are playing an entertaining game, we wouldn't notice the candle. Even if we do notice the candle, we wouldn't put a finger into the flame because we already know the flame will burn it. Unlike us, the little girl didn't know the property of a candle or its flame. When the girl noticed the candle, it was sensible for her to touch the candle because she had been touching and smelling new things to learn about them. So, she put her finger into the candle flame. In short, the girl tried to grab the candle flame not just because of the existence of a candle, but because of the context as a whole. Dewey (1938/1991) wrote, "The object or event in question is perceived as part of the environing world, not in and by itself; it is rightly (validly) perceived if and when it acts as clew and guide in use-enjoyment" (p. 73).

Dewey understood the construction of a problematic situation to be the result of an inquirer's interaction with various environmental elements that are relevant to disrupt the harmonious functional relation (T. Burke, 1994). The elements include the inquirer's lived

experiences, other people, material artifacts, physical conditions, culture, and language (Dewey, 1938/1988).[2,3] He wrote,

> What is designated by the word "situation" is *not* a single object or event or set of objects and events. For we never experience nor form judgments about objects and events in isolation, but only in connection with a contextual whole. This latter is what is called a "situation." (Dewey, 1938/1991, p. 72)

Dewey's perspective on a problematic situation as a contextual whole provides important educational implications. First, an object or event does not automatically create a problematic situation for students to initiate an inquiry. Even proven-to-work learning materials may not lead students to initiate an inquiry depending on the nature of students' experiences and their interaction with the environment—because a learning material is only one component in a situation, not a determinant of constructing a situation. Second, even if a learning material leads students' inquiry, they may engage in a different kind of inquiry than the one the teacher anticipated. Such diverse construction of a problematic situation is not something to be discouraged, however. It is just a natural process: Inquirers' different experiences inevitably lead to different interactions with the environment and a different construction of the situation.[4] Third, in order to encourage students' engagement in productive inquiry, teachers should understand students' experiences and their interactions within the given circumstances. Because students'

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[2] Despite the broad definition, a situation does not include everything in the entire environment. If we start including anything and everything in a given environment, taking account of a situation becomes an endless task and so does an inquiry. Rather, Dewey's situation consists of elements of direct relation in a problem and of the necessity to address the problem (T. Burke, 1994).

[3] Because an environment seems to connote only physical conditions, Dewey used a situation to include cultural, social conditions, and personal experiences as well.

[4] Acknowledging diverse construction of a situation shouldn't be confused with conceptualizing a problem as a purely psychological phenomenon—a puzzlement or confusion inside your head. The difference in recognizing a situation does not mean the situation does not exist but inside my head. Rather, a different construction of a situation should be interpreted as diverse functional relations. An event or object might have the potential to develop a problematic situation. Sometimes an event manages to disturb our functional relationship and leads us to recognize a problem in the context. Sometimes the event is not aligned with our experiences and does not lead to a problematic situation.

interactions are shaped by their experiences as a whole, teachers need to consider students'

emotional, social, and physical experiences, as well as their academic experiences. Below, I

further explore these points.

      Relevance of a school activity. According to Dewey's theory of inquiry, the creation of a

problematic situation is understood as the result of interactions between learners' experiences

and environments, and the learners' anticipation of the problematic situation is the starting point

of an inquiry. This means the learners' recognition of a problematic situation and the need to

address the situation is the driving force of inquiry. In *Art and Experience,* Dewey wrote,

> We have an experience when the material experienced runs its course to fulfillment. Then
> and then only is it integrated within and demarcated in the general stream of experience
> from other experiences….Such an experience is a whole and carries with it its own
> individualizing quality and self-sufficiency. It is an experience. (Dewey, 1935/1987,
> p.35)

An experience can be interpreted as a true inquiry experience. When an inquiry deeply relates to

the learner's lived experience, the power of relevance runs the course to fulfillment, and the

learner's experiences are reorganized to become a unified whole.

      Understanding relevance as the driving force of inquiry means that an irrelevant or

meaningless task cannot be regarded as inquiry. If the learner does not register an event as

problematic, s/he simply does not initiate an inquiry. Even if s/he participates in the task, the

information gathered from such an irrelevant task cannot successfully reorganize the experiences

and guide future actions. Thus, if a teacher attempts to teach a subject matter without considering

students' experiences, the effort cannot help but be wasted. Dewey (1938/1991) wrote, "To set

up a problem that does not grow out of an actual situation is to start on a course of dead work" (p.

112). Rather than setting up dead work, Dewey (1938/1988) recommended that for school

activities to become valuable teachers should endeavor to align them with students' experiences

because (a) students would initiate an inquiry when the activity relates to their lived experiences

in a meaningful way, and (b) thinking develops as a learner acts to figure out a genuine problem and resolve the situation (Dewey, 1916/1980). As the problematic situation becomes real to the learners, they would fully participate in addressing the situation and the inquiry would run its course to fulfillment. Myles Horton (2003) agreed, "If education is to be vital, it must deal with [learner's] situations, not the subject [per se]" (p. 215).

However, school activities are often presented as gathering a bunch of remote information without direct relevance to students' experiences, and students are not able to build valuable scientific knowledge for their lives (Tanner, 1988). This is partly because, unlike Dewey, we do not consider the relevance as a critical component; and partly because students may construct a situation quite different from what the teacher anticipated.

Diverse construction of a situation. Although teachers may endeavor to create an educational experience for students, teachers cannot fully anticipate the students' experiences, and the teachers' envisioned situation may not be directly translated into the students' situation. What are the teachers supposed to do when a learning material does not lead students to get engaged in a desired inquiry? Admitting diverse construction of a situation poses a great challenge to teachers.

I find Hawkins's (1965) case helpful. When he was to introduce the physics principles behind pendulum movement to elementary school students, he realized the diverse experiences of the students. Some had built quite advanced knowledge in physics, whereas others struggled with the basic concepts. Instead of directing students into a particular task, he allowed them to 'mess about' with the material freely because he wanted to give students a chance to explore the material in their own way. Students played with the pendulums and the classroom became chaotic. Some students brought a water tank and put a pendulum into it. Some cut different kinds of strings and put them through a pendulum. Hawkins worried if this was a waste of time and the

student activities wouldn't lead them anywhere. Soon, he realized that students' own exploration offered an invaluable opportunity for them to get acquainted with the material. Because they were free to do anything they wanted with the pendulums, the students used their interests and experiences to interact with them. The students concentrated on their own ingenuity, such as experimenting with an underwater pendulum. Their own explorations also included those that the teacher might have asked them to do—experimenting for differences in length and amplitude with different kinds of bobs. In using their own experiences, the students devised ways to interact with the learning materials, and they gained enormous scientific understanding from the activity. The students were intensely engaged in the task because they had a chance to conduct an inquiry of their own, without the teacher's hasty directions for the task.

What if Hawkins didn't allow the students to experiment with the pendulum for weeks? What if he discouraged the students' own investigations, like many teachers in school? Would the students have learned the same information? Reflecting on the experience, Hawkins (1965) argued that students should be given opportunities to explore the materials in their own way. The 'messing about' is not a waste of time, but an essential opportunity for students to connect the material with their experiences and learn the material without much teacher intervention.

Dewey would say that imposing on students to conduct a task the teacher's way, despite the diversity of students' experiences, is to lose the educational possibility of genuine inquiry. If students do not have ample opportunities to explore the material in their own way, they cannot make a connection and, in turn, fail to learn from the material. In order to provide an educative experience for all students, not only for those who can relate to the material the same way the teacher has envisioned, but for all others, teachers need to invite students' experiences and allow them to find ways to appropriate the learning material. That way, students are able to access science in meaningful ways. Thus, Dewey (1916/1980) urged teacher's openness of mind toward

the students' own dealings with a situation. He warned against the totalitarian approach in which teachers discourage students' own thinking and require them to follow the teacher's way: "The teacher who does not permit and encourage diversity of operation in dealing with questions is imposing intellectual blinders upon pupils—restricting their vision to the one path the teacher's mind happens to approve" (Dewey, 1916/1980, p. 175).

The diversity of experience does not mean that every classroom inquiry should be conducted individually without any teacher's guidance. What Dewey called for is more focus on what students learned rather than on what is presented or what is taught. What situations do individual students perceive problematic? How are they different from what the teacher planned? Why do the students construct the situation in a certain way? What do they want to change in the situation? How do they direct their inquiries to solve the problematic situations? What roles do various components of the situation (such as other people, material artifacts, culture, and language) play in the inquiry? How can I as the teacher help their inquiry? And, what have they achieved through the process?

Dewey (1916/1980) wrote that education is a process of helping students reconstruct or reorganize their experiences in a productive way. In order to help students reconstruct their experiences for fuller, more productive lives, teachers would need to encourage and guide students' own sense making of the environment with an intellectual hospitality and sympathetic attitude, instead of forcing their way of thinking on the students.

Understanding students' experiences. Because students' lived experiences determine the quality of a school activity for them (Dewey, 1902/1976a, 1938/1991), teachers need to endeavor to provide more educative experiences based on their deep understanding of students' experiences. To Dewey, experience means more than knowledge, but a complex, multidimensional life laden with values and emotions (Boisvert, 1998).

Understanding students' experiences in the science education field is often translated into surveying their knowledge in order to teach a topic effectively (Driver, Guesne, & Tiberghien, 1985; NRC, 2000; Rowan & Bourne, 2001). The survey often asks what students know or don't know about the target concept. It does not concern students' intentions on learning the topic or the application of the concept to our lives: for example, if they want to know about the phenomenon, why they want (or don't want) to know about it, how it relates to their lives, or how it can be used to solve a problem of their own. Without much consideration of students' needs, way of life, or possible application for their lives, understanding of experiences is often translated to a teaching strategy to diagnose misconceptions and effectively present the correct science concepts—as if students will eagerly try to acquire more scientific concepts once they realize they cannot successfully explain a natural phenomenon, no matter how it are related to their lives or identities.

Dewey (1938/1991) would argue that understanding learners' experiences should not be limited to only their cognition if we really want to teach science: "For we never experience nor form judgments about objects and events in isolation, but only in connection with a contextual whole" (p. 72). Pintrich, Marx, and Boyle (1993) argued that the cold conceptual change model overemphasizes the rational process of learning and fails to account for students' nonacademic experiences as an important moderator of learning. Even after the students realize their explanation is not fully scientific, they may opt not to learn a scientific explanation because they do not want to be regarded as a 'smarty pants', 'teacher's pet', or a 'show-off' by their peers. There are some sociocultural studies in which students are reported to find that learning science conflicts with their identity or worldviews and thus fail to learn science effectively at school (Aikenhead, 2001; Allen & Crawley, 1998; Barton, 1998b; Brickhouse, Lowery, & Schultz, 2000). Allen and Crawley (1998), for example, reported that when a teacher tried to motivate a

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group of Native American students with material rewards on a competition basis, the students, who very much valued collaboration, refused to compete and scoffed at the competitive materialism. These Native American students, who felt a strong kinship with nature and emphasized the harmonious relationship, were also scornful with the people's attempt to manipulate nature and refused to 'work with' animals in schools. In a different case, when a teacher asked her students to bring in a shoe box to learn the mechanism of a camera, a girl from a homeless shelter was too proud to borrow a shoebox from other students and failed to learn about cameras (Barton, 1998b). When given a chance, those students might have progressed in learning science more successfully, but the lack of understanding of students' identities and ways of living led the teachers to fail to guide students to find a meaningful connection of science to their life. Tobin (2002) wrote that while many teachers devote themselves to help students learn by making science lessons relevant, they often lack a deep understanding of students' nonacademic experiences—how they view themselves, how they interact with others, and what they desire most at school or outside school. Teachers often don't know how to draw from significant students' experiences. As a result, the effort to make science relevant falls short in reaching out and engaging students into scientific discourse (Tobin, 2002).

Dewey's idea about such a situation emphasizes that an act of learning (or inquiry) is a part of our interaction within the world. It is not just a cognitive operation and cannot be understood separately from our lives—including inquirers' goals to understand and navigate the world, build identities and values, and find their roles in the world. Because all these social, cultural, emotional, and cognitive experiences determine how and what we learn, teachers should work hard to understand students' lived experiences as a whole and include them when designing learning activities.

Dewey's Theory as an Analytical Framework

In contrast to the common understanding of inquiry as a hands-on learning activity or scientific process, Dewey defined inquiry as the way to learn and live. From our functional relation within the environment, he observed, we construct a problematic situation as a contextual whole and we put in effort to resolve the problem through reflective processes. When we combine the unique understanding of inquiry with his view on educational growth, we are able draw numerous educational implications and use them as an analytical framework. For the purpose of this study, I have focused on three aspects of inquiry and drawn three analytical components: (a) the relation of inquiry questions to learners' experiences; (b) the mode of learners' engagement in learning; and (c) the impact of the inquiry on learners' individual and communal life. These three elements of inquiry suggest alternative ways to evaluate school activities and students' participations.

Inquiry components

Relevance. Although we tend to think little of our ordinary experiences, their importance appears repeatedly in Dewey's writing. As the core of human inquiry, Dewey observed our ordinary experience possesses enormous possibilities for our growth, "if we but allow it to bathe over us in its own terms" (J. J. McDermott, 1981, p. x). He also understood inquiry as an effort to "establish continuity and meaning in experience" (Phillips, 2001, p. 6). Making sense of our present experiences—what meaning we draw out of them, how we take meaning from of them, and what we do with them—even defines our being (Bruce, 2008). Because of its critical role in helping an inquirer to grasp the fuller meaning of the world and grow intellectually, socially, and morally, Dewey (1938/1988) asserted that the ordinary experience of students needs to be the center of school learning. Education is always an activity in the present, the practice of extracting meaning from current conditions. Thus, school activities need to be drawn from students' present

ordinary experiences, and school learning needs to be effectively integrated into experiences (Boisvert, 1998).

Relevance in the analysis refers to the level of connection of the inquiry activity to students' personal and social life. Dewey viewed scientific inquiry as a tool to address our concerns and advocated that students "explore and grapple with the real problems of their home and community" (Rudolph, 2005, p. 811). He argued that school activities need to connect effectively with the student's experiences to create a problematic situation for desired learning.

Although the common rationale for adopting inquiry-based education is its direct connection to students' experiences, we adopt various models of understanding the experiences and consequently different ways to tap into students' interests. To determine the relevance of learning activities across different settings, I focus on three quality-of-inquiry questions and goals: (a) how the inquiry question relates to the students' immediate experiences; (b) how the activity utilizes students' social, cultural, and experiential resources; and (c) and how the activity aims to facilitate students' growth.

Participation. With the frame of inquiry as a continual process of interacting within the environment, Dewey emphasized participatory action as the primary way of gaining knowledge and exercising intelligence (Connell, 1994). Because our knowing emerges as a consequence of our action within the world, Dewey believed school should provide an environment for students to actively engage in important matters of their lives—as an extension of their everyday lives rather than as an artificial suspension of them (Dewey, 1916/1980). Students' participatory action, however, needs to be facilitated so that they are able to realize democratic values, such as collaboration, respect, and reflection, to live harmoniously in the community.

> I believe that the only true education comes through the stimulation of the child's powers by the demands of the social situations in which he finds himself. Through these demands he is stimulated to act as a member of a unity; to emerge from his original narrowness of

action and feeling and to conceive of himself from the standpoint of welfare of the group to which he belongs. (Dewey, 1897/1998, p. 229)

Our interaction in the world simultaneously involves various participatory aspects including: understanding and navigating our surroundings intelligently; negotiating values in a community; finding our roles in the world; and changing the world to a better place to live. For the analysis in this study, I focused on two aspects for participation: collaboration and reflection. The collaboration aspect looked at the relationship students were building through the project: how students interacted with one another, and how students contributed to the development of the project. Reflection meant how productively and reflectively the students participated in the activity to improve the quality of inquiry. Although inquiry-based learning activities tend to provide more collaborative and reflective classroom environments than traditional instruction settings, some projects may not afford much chance for students to exercise their collaborative and reflective attitudes in class.

Significance. Because Dewey appreciated inquiry as a dynamic, functional interaction between the inquirer and the environment, inquiry outcomes could not be contained in the individual inquirer's mind. Rather, it needed to be understood as a transactive action on the problematic situation—change in the interaction between the inquirer and the environment in some way.

> Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But this is not the whole of the story. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had. (Dewey, 1938/1988, p. 22)

Dewey's transactive view on the inquiry leads us to focus on the consequences of inquiry beyond the internalized knowledge. What are the major impacts of the inquiry on our personal and communal life? How does our inquiry contribute to changing our school, home, or community environments for the better?

The outcome of the inquiry or the consequences of the inquiry on students' life needs to be measured for this last category. While the outcome of inquiry-based education was often measured only by students' knowledge gains, I looked for a significant transformation of the situation: what impact the inquiry had on the problematic situation; how it helped the inquirers' growth; and how the inquiry project initiated further inquiry for students.

Analytical scheme of this study. Drawing from Dewey's theory of inquiry, I selected three inquiry components and arranged related questions in each category (see Figure 1). The list served as a component checklist to identify and compare the main features of inquiry-based learning projects or classroom interactions in various settings.

Key Questions

Relevance: Connection to students' experiences

> How did the inquiry address a significant problem of students' personal and social lives, in contrast to artificial, simulated problems?
>
> How was the activity understood in relation to the students' own experiences?
>
> How did the activity utilize the cultural, experiential resources of students?

Participation: Inquiry with reflection and collaboration

> How did the students contribute in the design and operation of the activity?
>
> How collaboratively did the students interact with others?
>
> How reflectively did the students examine the progress of the inquiry?

Significance: Meaningful transformation of the situation

> What changes did the inquiry effect on the problematic situation?
>
> How did the activity help students participate in their life matters better?
>
> What further inquiry did the activity initiate?

Figure 1. Inquiry component checklist.

Based on the component checklist, I drew a simple triangle to help visualize the characteristics of each project or activity (see Figure 2). The vertices of the triangle represent the three components of inquiry—relevance, participation, and significance. The distance of each vertex from the center of the triangle represents how strongly the component was implemented in the activity. For example, if students investigated important questions of their lives, they participated and reflected on the activity to its fullest, and the project successfully changed the problematic situation and made a significant impact on their lives. The exemplary case would mark very strongly in each component and the inquiry component triangle would look like (a) in Figure 2. If a teacher lectured on important scientific matters in the students' lives without giving them a chance to investigate and act on the problem themselves, it would score relatively strong on relevance but fairly weak on participation and significance. The inquiry component triangle for this case would be a small and long isosceles like (b) in Figure 2. The inquiry component triangle is not, by any means, an attempt to bury the complex interplay of various contextual components of each case. Rather, it is an attempt to visualize the major characteristics of each case that are often buried in long, detailed description of cases.
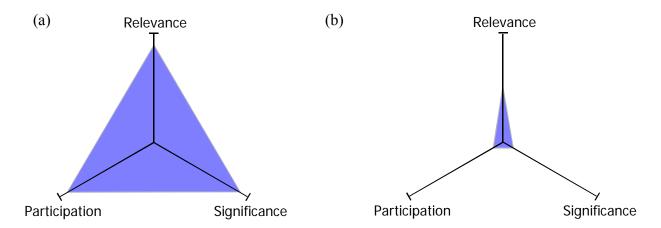

Figure 2. Inquiry component triangle model. (a) Inquiry component triangle for an imaginary exemplar inquiry project; and (b) inquiry component triangle for an imaginary one-way lecture addressing a significant problem of students' life.

Chapter 3

National Science Education Standards

Realities of Inquiry-Based Education and the Standards

Inquiry has been a focal word in science education research for many years (R. D. Anderson, 2002; Barrow, 2006; Duschl & Grandy, 2008; Keys & Bryan, 2001). Many educators have studied better ways to implement inquiry-based education in school settings. Some have developed inquiry-oriented science curricular materials (e.g., Edelson, 2001; Linn, Clark, & Slotta, 2003; Songer et al., 1999; White & Frederiksen, 1998) and supplemented them with detailed curriculum guides (Schneider, Krajcik, & Blumenfeld, 2005), professional development workshops (Radford, 1998; Songer, Lee, & McDonald, 2003), and continuous on-site observation and support (Fishman & Krajcik, 2003; Songer, Lee, & Kam, 2002). Others have explored various venues of inquiry-based education (Bransford, Brown, & Cocking, 2000), including scientist apprenticeship (Barab & Hay, 2001), authentic scientific inquiry (Chinn & Malhotra, 2002), new teacher roles (Crawford, 2000), and new student roles (Carlone, 2004).

Despite extensive efforts to implement inquiry, educators have found that they have not penetrated the mainstream of science education (R. D. Anderson, 2002; Barrow, 2006; Huberman & Middlebrooks, 2000; Welch, Klopfer, Aikenhead, & Robinson, 1981). At the state or district level, a large portion of science education goal statements are content-oriented rather than inquiry-related (Eltinge & Roberts, 1993; Welch et al., 1981). Science lessons nationwide pay minimal attention to inquiry—15 percent of the class hour in elementary schools and two percent in high schools (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Many teachers do not attempt more than simply having students read about science topics from their textbooks (Stake & Easley, 1978). Simple cookbook-style, confirmative experiments are still the norm for labs

(Chinn & Malhotra, 2002; Germann, Aram, & Burke, 1996; Volkmann & Abell, 2003). Only a small percentage of schools use inquiry-based curricular materials (Chinn & Malhotra, 2002; Welch et al., 1981), and even those with well-intended innovative curricula are often used as watered-down versions of algorithmic, structured instructions with few hands-on components (Fishman & Krajcik, 2003; Huberman & Middlebrooks, 2000; Schneider et al., 2005). Teachers are reported to revert to didactic teaching practice even after experiencing inquiry-based teacher education programs (Schneider et al., 2005).

The disappointing reality of implementing inquiry-based science education is often explained by the teachers' lack of understanding of inquiry-based teaching (Alberts, 2000; Radford, 1998). Even after workshops and on-site support, many practicing teachers continue to think of inquiry-based teaching as letting students do hands-on activities (Crawford, 2000) or deem inquiry as too difficult to manage within ordinary teaching environments (Barab & Luehmann, 2003; Henry, 1996; Stake & Easley, 1978). Other studies suggest that the current school structure does not support inquiry-based education in its full form. Inadequate school resources, time, and expertise seem to thwart teachers' effort to implement inquiry-based education (Barton, 1998b; Huberman & Middlebrooks, 2000; Songer et al., 2002; Welch et al., 1981). In addition, with the strong accountability system in operation, teachers feel obligated to teach facts, information that shows up on tests, through traditional didactic instruction rather than to engage students in inquiry (R. D. Anderson & Helms, 2001; Barab & Luehmann, 2003; Welch et al., 1981).

In an effort to help systematically overcome this disappointing reality, various education standards have been established. The most often cited are *Benchmarks for Scientific Literacy* developed by the American Association for the Advancement of Science (1993), and *National Science Education Standards* by the National Research Council (1996). The rationale of such

efforts is that standards offer a set of comprehensive and practical guidelines to help teachers implement inquiry in current school settings (Alberts, 2000; R. D. Anderson, 2002; Bybee, 2000; Wheeler, 2000). They also aim to define a consensus on inquiry-related educational goals and work as a clear reference for science education researchers because inquiry-based teaching is used in various ways and the term is often too vague for coordinated efforts (Barrow, 2006; Bybee, 2000; Cuevas, Lee, Hart, & Deaktor, 2005; Wheeler, 2000).

Despite these ambitious intentions, the standards have received mixed responses. For the National Science Education Standards (NSES), some science educators and professional organizations have praised the guidelines as thorough, innovative, and practical (Alberts, 2000; Bybee, 2000; National Science Teacher Association, 1998; Wheeler, 2000). They argue that teachers should fully adopt the NSES so that they can embody inquiry-based science in their instruction. On the other hand, others have critiqued that the NSES is based on a limited sense of inquiry-based education, especially for socially underserved student groups, and have called for a more inclusive vision to achieve scientific literacy (Barton & Osborne, 2001b; Eisenhart, Finkel, & Marion, 1996).

Regardless of the disagreement, the NSES is often referred to as the definition of inquiry-based science education (Minstrell & van Zee, 2000). Its easy accessibility and wide references cause it to be recognized as a consensus regarding what we want to achieve from inquiry-based teaching and learning. Thus, I chose *Inquiry and the National Science Education Standards* (NRC, 2000) as a proxy for current educational goals and common assumptions.

Inquiry in the National Science Education Standards

The NSES (NRC, 2000) lists three types of inquiry.

1. Inquiry as teaching strategy: Engaging students in scientific inquiry through hands-on experiments,

2. Inquiry as content: Developing scientific inquiry skills,

3. Inquiry as content: Understanding of nature of science or scientific inquiry.

Inquiry as teaching strategy is a constructivism-based teaching approach in which teachers encourage students to build scientific meanings through concrete, engaging learning materials. The other definitions of inquiry are the desired learning outcomes to achieve scientific literacy. By learning about the nature of scientific inquiry and building skills to perform scientific inquiry, students are prepared to perform and understand scientific inquiries later in their lives. Based on this distinction of inquiry as the end result from inquiry as the means, I describe the following three aspects of inquiry in science education.

Content standards for scientific literacy and learning of scientific inquiry. The content standards consist of three parts: science concepts, scientific inquiry skills, and the nature of science. Below, I describe the common understanding of two elements: (a) acquiring the skills for scientific inquiry, and (b) understanding the nature of scientific inquiry.

Scientific inquiry skills. The importance of science as a habit of mind has been repeatedly recognized. Dewey (1910/1976) claimed, "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter" (p. 70). Schwab (1960) argued that because science is not a stable body of established results but a dynamic process of inquiry, we should teach science as a method of thinking. The

NSES (NRC, 2000) states that science should be understood as a way of acting and knowing rather than a stack of content knowledge.

In order to teach science as a way of thinking, we often categorize the procedural inquiry abilities and try to develop those skills in students: identify scientific questions; design and conduct a scientific investigation; analyze and interpret data; develop explanations based on the evidence; communicate and justify the explanations (NRC, 2000, p. 29). Although the procedural descriptions of inquiry do not offer a complete picture of scientific inquiry, they help students to practice scientific reasoning and yield valuable thinking strategy (Finley & Pocovi, 2000; van Zee, Hammer, Bell, Roy, & Peter, 2005).

Despite the educational benefits of following scientific procedures, science teachers need to be aware that such a discrete, linear procedure of scientific method does not illustrate what scientists actually do (Finley & Pocovi, 2000; McGinn & Roth, 1999; Windschitl, 2004). There is no single scientific method that represents how scientific investigations work. Different questions call for different methods, and different methods bring different answers. All phases and components of inquiry are interdependent with one another (Windschitl, 2004). Thus, blindly advocating the scientific method separately from the problem context not only prevents students from developing skills for scientific inquiry, but also obscures the situated nature of the scientific inquiry (Finley & Pocovi, 2000; McGinn & Roth, 1999).

Recognizing the limitation of teaching simplified inquiry abilities, educational researchers have insisted on adopting more realistic scientific inquiry in schools in order to help students develop an understanding of and skills related to science (Lunsford, Melear, Roth, Perkins, & Hickok, 2007; Rahm, Miller, Hartley, & Moore, 2003; Varelas, House, & Wenzel, 2005). Science educators expect that scientifically authentic learning opportunities help students to build scientific reasoning skills and understanding of the nature of science and hopefully to

become legitimate participants in the scientific community (Richmond, 1998; Varelas et al., 2005). The NSES thus suggests that students should experience the full range of scientific inquiry in their science classrooms to correspond to what and how real scientists work (McGinn & Roth, 1999; NRC, 1996, 2000).

To better understand authentic scientific inquiry experience and promote it in schools, researchers delved into what real scientists do and compared that with school science activities (Chinn & Malhotra, 2002). Some educators have developed curricular materials to reflect aspects of scientists' inquiry, such as complex data analysis (Edelson, 2001). Others have adopted an apprenticeship model and connected practicing scientists with students so that they can experience real scientists' work (Barab & Hay, 2001; Richmond, 1998). Inservice and preservice teachers also participated in science laboratory work in universities to use the experience for their science teaching (Radford, 1998; Varelas et al., 2005).

Nature of scientific inquiry. Science is recognized as an approximation of the natural world through rigorous and collective investigation within given circumstances, but at the same time, as any other human enterprise, science is a result of sociopolitical construction (Kuhn, 1977). The contemporary view on the nature of science includes (a) science as an effort to explain natural phenomena; (b) scientific knowledge as tentative; (c) science as empirical or observation-based; (d) observation as theory-laden; (e) scientific ideas as inference- and creativity-derived; and (f) science as a socially and culturally embedded practice (Abd-El-Khalick, 2004; Lederman, 2004; McComas, Clough, & Almazroa, 1998; Zeidler, Walker, Ackett, & Simmons, 2002).

Although science educators try to provide opportunities for students to experience authentic scientific inquiry, researchers have found that schools lack the time and resources to reproduce complicated scientific research tasks, and school inquiry projects often fall short of

fully reflecting the complexity and dynamic nature of science (Chinn & Malhotra, 2002).

Research studies show that students hold quite different views on scientific knowledge from the

contemporary understanding of the nature of science even after doing inquiry projects in school

or studying the history of science (Abd-El-Khalick & Lederman, 2000; McComas, 1998;

McComas et al., 1998; Schwartz & Crawford, 2004). In order to help students to understand

"science as it really is rather than promote a mythic view on science" (Martin, Kass, & Brouwer,

1990, p. 541), science educators are urged to deliberately and explicitly teach the nature of

science (Abd-El-Khalick & Lederman, 2000; Schwartz & Crawford, 2004). Some educators have

paid special attention to the socioethical issues of science (regarding human cloning and

environmental issues) to raise students' awareness and examine the interaction between science

and moral reasoning (Sadler, 2004; Zeidler et al., 2002).

Teaching standards and teaching science through inquiry. Teaching science through

inquiry as a teaching strategy derived from the critique of 'traditional' didactic teaching

strategies. When we think of a traditional classroom, we often picture an instructor talking about

abstract concepts while students sit quietly and take notes (Alberts, 2000; van Zee et al., 2005).

Teachers are often concerned about the 'coverage' of various scientific facts and focus on how to

organize and present important concepts so that students can understand them (R. D. Anderson,

2002; Minstrell, 2000a; Welch et al., 1981). Students memorize scientific facts and fill in a series

of blanks in tests (Alberts, 2000; Aldridge, 1992). But the hard-memorized scientific facts fail to

lead to an understanding of science. Rather, they are wiped clean out of students' brain as soon

as the tests are over (Aldridge, 1992; C. W. Anderson, Holland, & Palincsar, 1997). Surveys

show that in coverage-concerned didactic science classes, students' understanding is pitifully

shallow (Aldridge, 1992).

The ineffectiveness of didactic science instruction has been explained by constructivism research studies (Bransford et al., 2000; Fosnot, 1993; von Glasersfeld, 1995). Constructivism studies have shown that people learn and construct knowledge by connecting new experiences to what they already know. When new information is given without connection to the learners' prior understanding, it is ignored or leads to misunderstanding (Driver et al., 1985). Well-prepared presentations of information just doesn't work because knowledge cannot be directly transmitted from teacher to students (Driver et al., 1985; Jarrett, 1997). According to the NSES (NRC, 1996), "Learning science is something students do, not something that is done to them" (p. 20).

Based on the study of nature of science, science educators also argue that didactic instructions offer an illusion of science as certain, unproblematic, and authoritative (L. Bencze & Hodson, 1999). Didactic teaching and cook-book style labs provide a false sense of security and lead students to focus on finding the right answer (L. Bencze & Hodson, 1999). Alberts (2000) wrote,

> [Didactic instructions] fail to provide students with any sense of what science is, or why science as a way of knowing has been so successful in improving our understanding of the natural world and our ability to manipulate it for human benefit. (p. 9-10)

Because both learning and doing science are the active process of reconstructing one's own knowledge, constructivist science educators have argued that teachers need to pay attention to students' initial knowledge and provide ample opportunities for students to explore a scientific phenomenon freely to construct their knowledge (Bransford et al., 2000; Driver et al., 1985; Minstrell, 2000b).

In addition, science has long been recognized as a school subject that only a selected few can successfully learn. Yet, it is important to have the ability to think for ourselves and make decisions in science-related issues, especially in the society of science and technology

advancement. Scientific literacy, fostered through inquiry-based learning, helps us to make informed decisions of personal and social import, such as health and medical decisions, social policies, and other matters in our daily lives. It is argued that if more people become scientifically literate and participate in scientific inquiry in their lives, the more sensible, intelligent, productive, and democratic the society becomes (C. W. Anderson et al., 1997; Eisenhart et al., 1996; NRC, 1996).

The NSES (NRC, 2000) summarizes what it means to teach science through inquiry for scientific literacy: (a) Because students build new knowledge on what they already know, teachers need to utilize students' prior understandings in their teaching; (b) Because understanding science is more than knowing facts, students need to experience authentic scientific inquiry; (c) In order to encourage effective learning, teachers need to guide students to engage in developmentally appropriate questions that are scientific and relevant (p. 24-33, and 116-20).

Analysis of Educational Assumptions in the NSES

The NSES includes various aspects of inquiry for science teaching and learning and captures a few major elements of inquiry-based education. I have found, however, that some of their suggestions are misleading or contradict its own goal statements. Who decides the manageability and scientific authenticity in students' inquiry? How do we judge the quality of students' inquiry? What is the main role of relevance in school tasks for students' learning? What are the differences between scientists' inquiry and students' inquiry? What is the relationship between achieving scientific literacy and imitating scientists' inquiry? The inconsistency or inarticulateness of the NSES may cause unanticipated dilemmas in implementing inquiry-based science education and fall short of drawing support from science

educators. Using Dewey's theory of inquiry, I critically examine the NSES for scientific literacy and the role of students and teachers.

Engaging students in scientific inquiry. The NSES (NRC, 2000) places strong emphasis on the special qualities of scientific inquiry because students' understanding of and engagement in scientific inquiry helps them to build their ability to think, talk, and act like scientists (Richmond, 1998). Yet, the meaning of scientific inquiry is defined as a distinct type of enterprise in the scientific community, quite different from our everyday sense making. Although there are benefits to contrasting scientific inquiry with our usual way of thinking, the distinction seems to send an unintended message discouraging students' participation and identification with scientific inquiry. In this section, I explore an alternative view on authentic scientific activity.

Distinction between scientific inquiry and students' inquiry. In the NSES, scientific inquiry is defined as "ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (NRC, 1996, p. 23). Because science is recognized as intellectual work performed by the elite scientists, authentic science is understood as something with special structures and qualities, quite different from our usual way of thinking (Buxton, 2006; Chinn & Malhotra, 2002; Lee, 2002; Rahm et al., 2003; Rudolph, 2005). To clarify the quality of scientific inquiry, the NSES (NRC, 2000) lists a few nonscientific questions[5] that students often raise and contrast them with scientific ones. As a result of such

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[5] The NSES (NRC, 2000) suggested that 'how' questions are better for school science than 'why' questions because why questions are existential questions, whereas how questions are causal questions that "lend themselves to scientific inquiry" (p. 24). Such mechnical division of how and why questions (as scientific versus nonscientific investigation) is in a way misrepresenting science. Science is an empirical study, and observation of casual effects is a good part of science. How-questions often lead to a collection of observational data (e.g., how does A change in relation to B?), whereas why-questions lead to literature research and modeling of the unobservable. But just describing what happens based on a how-question is not the whole part of science because a phenomenological description only does not equal a scientific inquiry. Science, as I understand it, is a human effort to explain *why* natural phenomena happen the way they do. Ironically, the NSES document also shows why-questions in the case examples

understanding of authentic science, "In schools, science is represented as a particular kind of exclusive discourse that one must master, a dispassionate discourse that relies on special structures" (Gallas, 1995, p. 7).

The clear contrast between scientists' and students' thinking privileges the scientific way of knowing over our daily sense making. Such a distinction between the scientific and nonscientific way of knowing is clearly shown in the literature about children's representation of scientific concepts (e.g., Driver et al., 1985). Such studies focus on the differences between science and students' experience and regard them as discontinuous and contradictory (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Especially in studies of sociohistorically underserved students' learning of inquiry-based science, students' discourses are recognized as incongruent with the scientific discourses (Delpit, 1988; Fradd & Lee, 1999; Henry, 1996; Lee & Fradd, 1998). In other words, minority's cultural resources are understood as a barrier for them to absorb the practice of the professional scientific community and to be able to conduct a scientific inquiry (Barton, 1998a; Lee & Fradd, 1998). Delpit (1988) thus argued that minority students need to acquire the dominant scientific discourse through explicit instruction on the rules of participation.

Issues of emphasizing specialists' science. The distinction between knowing by scientists and by students sends a mixed message. The NSES is intended to engage students in productive learning activities so they experience high-quality inquiry and build the ability to think and act scientifically in their daily lives. By emphasizing the difference between scientific inquiry and students' inquiry, however, the NSES implies that students' inquiry should resemble

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of inquiry. The main question for the geologist's inquiry in Chapter 1 is '*Why* are so many trees dead in the area?' Also, the question for the corresponding classroom inquiry in the same chapter is '*Why* are those trees on the playground different?' The existential questions led to good scientific inquiries for both cases. Then, why does the NSES discourage investigating why-questions in school science as a whole?

scientists' inquiry with its special structure and quality, and that students should follow and master *the* correct way of doing scientific inquiry. Such recognition of scientific discourses invokes some difficult issues. I list three of them in relation to our effort to teach for scientific literacy.

First, the distinction between scientific inquiry and student's inquiry often forces a divorce of science learning from everyday sense making (Eisenhart et al., 1996). Students realize their everyday sense making is different from school science, and they feel they need to suspend their own cultural resources to become successful in school (Aikenhead & Jegede, 1999; Eisenhart et al., 1996). Walkerdine (1988) found that the degree of students' ability to suspend their everyday discourse increases their chance to become successful in school work. This understanding that school science does not address everyday sense making not only blocks deeper understanding of science concepts, but it also minimizes the role of science in people's lives (Bruce, personal communication, 2006). When students learn to isolate science from their everyday sense making, they are not likely to practice science outside school walls. Rather than using science as a tool to understand the world around them and make differences in their lives, students regard it as one of school subjects they leave behind upon graduation. This exclusive understanding of science prohibits science to become more relevant and powerful in people's lives. This is especially unfortunate because the main goal of the NSES is to raise scientifically literate students who can think and talk science outside school walls.

Second, when students perceive that science doesn't value their way of thinking, they resist learning scientific discourse and withdraw from participating in science (Carlone, 2004; Eckert, 1990; Eisenhart et al., 1996). Even in reform-based science classes, a majority of students believe science is a privileged way of knowing and they resist taking part in discussion because they are afraid to get ridiculed or damage their otherwise favorable student identity for

not speaking scientifically (Carlone, 2004). The authoritarian conception of science keeps students from participating in scientific discourse and diminishes their chance of participating in democratic decision making on various scientific issues. Because people are accustomed to privileging science (or scientists) over their own thoughts, science-related issues have often been delegated entirely to scientific authority, and the public involvement in science issues has been minimal (Gieryn, 1995; Rudolph, 2005). The decisions regarding scientific issues are bound to affect the public at various points in our lives, for example, whether to fund stem cell research that will affect people who suffer from Parkinson's disease and other fatal illnesses; the development of new high-tech weapons that will affect the dynamics of world peace and eventually the funding for teachers, students, and educational research. Often without sharing the decision-making process in scientific issues, people have borne the consequences in our current science- and technology-rich society. Dewey pointed out that in a democratic society, people should have a fair share in making decisions that will affect them (Harding, 1991). Such democratic decision making seems hard to realize with the exclusive view on 'science versus common sense'.

Third, the perceived conflict between school science and minority students' cultural resources negatively affects minority students' identity and discourse. If minority students want to become successful in science, they will need to cross the cultural gaps between their own discourse and correct scientific discourse (Aikenhead, 2001). As they try to replace their own situated discourse with the discourse of scientific rationality, they are often discouraged in their effort, and end up devaluing their cultural resources (Eisenhart et al., 1996; Warren et al., 2001). This is regrettable not only for minority students, but also for the field of science. By focusing only on propagating the normative Western science in student's minds, school science weeds out students with different cultural resources and loses their contributions of alternative ways of

thinking in the science field (Barton & Osborne, 2001b; Harding, 1991). Harding (1991) explained that such exclusive practice keeps the field of science trapped in its own biases and leads to failure in generating a more productive, complete understanding of the world. She thus argued that we need to have more inclusive participation in scientific research in order to construct a less prejudiced and less distorted understanding of the world.

Overall, those issues show that the elitist view of science in the NSES works against the stated aim of involving students in meaningful inquiry-based learning for scientific literacy (Barton & Osborne, 2001b; Eisenhart et al., 1996). Especially for students who are traditionally marginalized in science, the exclusive perspective prevents students from participating in inquiry activities and building a deeper understanding of science inside and outside of school. It prevents them from identifying themselves with science and becoming lifetime learners of science. Furthermore, it hinders the science field from building fuller, influential, and democratic knowledge.

Alternative view on scientific authenticity. The discussion on the privileged understanding of science invokes a question: Is science really different from common sense? The common-sense answer is "yes." Especially when we enter a room with big high-tech machines and complicated charts, the amazement is quickly translated into the difference between the layperson and the scientist, the commonsensical and the scientific way of knowing. Such conceptualization of science as the specialists' way of thinking is widely accepted and has deep historical roots (Wong, 2002). Aristotle characterized science as the timeless effort to describe the laws of nature, whereas practical activity is mainly concerned with human society. Descartes privileged rationality and science over other forms of understanding because truth and defendable decisions come from rational thinking rather than from social or individual experiences. Later, science was further distinguished by different goals, knowledge structures,

and methods. Careful coordination of evidence and explanation, complete and systematic testing of variables, and close attention to the consistency of ideas contributed to the unique features of science, apart from everyday thinking.

Dewey (1938/1991) also acknowledged that people conceive science different from other sorts of knowledge. But he argued the difference between common sense and science is overemphasized. Science is simply an intellectual control of the everyday world, and scientific subject matter and procedures grow out of the direct problems and methods of common sense. Scientific inquiry is our effort to solve the problems in our life and reach a sensible and defensible knowledge claim. Dewey argued that although the enterprise of science hides its link to everyday life for bystanders to understand, science by its nature cannot be separated from common sense and the everyday world. Instead of conceptualizing science as a technical enterprise withdrawn from our experiences, we need to understand science is a tool that enables us to enlighten and reorganize our experiences.

Dewey's view on the functional relationship between science and our experiences is echoed by contemporary science philosophers. Feminist science philosophers (e.g., Harding, 1991) understand science as a situated practice in social contexts and individual experiences. Studies in the nature of science also show that scientists do not conduct scientific inquiry based on a preset methodology. Rather, they use available materials and methods in given contexts to reach a sensible conclusion in relation to our experiences (Feyerabend, 1978; McGinn & Roth, 1999; Wong, 2002).

Dewey's understanding of science in close relation to our experiences provides an alternative view on authenticity. Science education studies often try to resemble elite scientists' inquiry procedurally or epistemologically in order to secure scientific authenticity (Barab & Hay, 2001; Chinn & Malhotra, 2002). Dewey wouldn't agree with this approach. First, the scientific

process is operationally constructed and reconstructed through ongoing inquiry to best address

the situation (Dewey, 1938/1991). It is meaningless to force students to follow an independently

set methodology to make the process scientifically authentic (Buxton, 2006; Stuhr, 2002). Rather

than comparing scientists' inquiry process to students', we need to see how students develop

appropriate methods to address the situation in given circumstances and judge the scientific

authenticity accordingly. Second, science is our effort to enlighten and reorganize our

experiences (Dewey, 1938/1991). If an inquiry does not help reconstruct our experiences in a

meaningful way, it does not function as a scientific inquiry even if it has the procedural

complexity and accuracy. Unless the inquiry has a direct link to our experiences, it cannot be

called an authentic inquiry.

Rather than defining scientific authenticity based on the procedural resemblance to

scientists' inquiry, Dewey would define scientific authenticity based on its meaningfulness to our

experiences and the defendability of its knowledge claim. Because Dewey understood science as

a situated effort to address problems of our life, an inquiry is scientifically authentic when it

makes our action meaningful and intelligent in given circumstances. Here, the authenticity is not

given from outside science experts. It is constructed through the inquirer's interaction with the

science activity and local environments. Dewey's conception of authenticity could be called

experience-based or contextual authenticity (Buxton, 2006; Doyle, 2000; Rahm et al., 2003).

Based on this contextual, experience-based authenticity, teachers and students need to

pursue investigations of their experiences, devise the processes, and build sensible knowledge

claims, instead of trying to imitate the procedures of scientists' work practice (Buxton, 2006;

McGinn & Roth, 1999). This experience-centered authenticity can be easily interpreted as

ignoring the structure of science in educating the young. Dewey (1902/1976a), in *The Child and

the Curriculum*, cautioned we should drop the notion of students' experience versus scientists'

practice in the curriculum. The sectarian opinions which contrast the emotional child versus logical subject matter are unproductive (a) because for the children, learning is a matter of linking their experiences—attitudes, interests, and knowledge—with the subject matter; and (b) because the subject matter is neither ready-made in itself, nor outside our experiences. Dewey (1902/1976a) argued that students' experience and scientists' practice are not discontinuous opposites but two components in a dynamic continuum to define a curriculum.

> Abandon the notion of subject-matter as something fixed and ready-made in itself, outside the child's experience; cease thinking of the child's experience as also something hard and fast; see it as something fluid, embryonic, vital; and we realize that the child and the curriculum are simply two limits which define a single process. Just as two points define a straight line, so the present standpoint of the child and the facts and truths of studies define instruction. It is continuous reconstruction, moving from the child's present experience out into that represented by the organized bodies of truth that we call studies. (Dewey, 1902/1976a, p. 189)

If we take Dewey's idea of learning as the dynamic relation of subject matter and children, we need to drop the idea of a gap between the child's experience and subject matter. Instead, we need to see how children's experience already contains within itself elements of formal studies and how it helps them learn science.

Aligned with Dewey's idea, some science educators have investigated the continuum of everyday sense making and science learning. Warren and her colleagues (2001) studied how students' cultural resources help they learn science. When Haitian and Latino immigrant children discussed metamorphosis, their everyday way of talking with analogy and concrete visual examples helped them make better sense of the phenomena. While imagination and attachment to objects are regarded unscientific, it helped the students consider the behavior of insects and explain their experiments. Instead of discouraging students' everyday reasoning and imagination as unscientific, Warren and her colleagues focused on how it actually worked as a valuable intellectual resource to make sense of science, and how scientists also take the perspectives of

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objects and common sense. Although we often consider that students'—especially minority students'—discourses lack the complexity or precision of scientific discourse, the researchers argued that students have enough intellectual power to use their cultural resources and deal with complex issues of science when circumstances are right. What educators need to do is not admonish students' cultural resources but devise better ways to cultivate them for science learning.

In a similar effort to defy the conception of the absolute gap between science and our experiences, some researchers have explored the cross section of science and personal experiences in scientists' work (McGinn & Roth, 1999; Osborne & Brady, 2001; Wong, 2002). Wong (2002) studied the life of practicing scientists to illustrate how science has personal meanings for practicing scientists. He reported that an autistic scientist felt tranquil from tight squeezing, and she devised a chamber for holding cows. By transferring a personal experience to a scientific procedure to provide comfort to animals, the scientist felt contentment in her work. Another scientist, a physicist, was not initially very successful in building machines. He tried to overcome the weakness and continued to keep at it. As he conducted scientific experiments utilizing his own machines, he felt great achievement. To those scientists, science is not something that exists outside personal experiences. Rather, it is something closely woven into their lives, their enjoyment, and satisfaction.

> The vitality of science is the dynamic relating of individuals' lives, their work, and their ideas. Scientists are made more alive and more fully human in their science as they experience a greater capacity for action, feeling, and thought. To do science is to be inspired. To inspire is literally to breathe life into something. The goal of education is for science students to appreciate this vitality and to be similarly inspired. (Wong, 2002, p. 396)

Science in ordinary people's lives. The link between science and our experiences can be explored from another angle through finding science is not just in scientists' labs but in many

ordinary places. For example, environmental activist groups obviously use scientific data and discourse for their cause (Eisenhart & Finkel, 1998); nurses scientifically evaluate medical evidence from patients and medical resources to consult with their patients (Aikenhead, 2005); Layton, Jenkins, Macgill, and Davey (1993) illustrated how ordinary people use science in workshops to transform scientific knowledge into solutions for personally significant problems in their lives. Such cases show the importance of ordinary people having scientific literacy. Brickhouse (2008) asserted that to achieve scientific literacy, we need to broaden our perspective on science itself—science for ordinary people and their experiences, not just for scientists.

Summary: Understanding scientific authenticity in relation to students' experiences. The term scientific authenticity was originally adopted to move didactic science lectures to activity-rich inquiry-based instructions. However, by defining scientific inquiry within the boundary of scientists' work as in the NSES, we inadvertently emphasize the technical aspects of scientific inquiry and admonish students' social and personal experiences. This practice limits diverse students' full participation in school science activities. Rather than considering science to be separate from our everyday experiences, Dewey urges us to regard science as a tool to make better sense of the world and make our inquiry more intelligent. Based on its intimate functional relation, Dewey informs us that science without a direct link to our social and personal experiences cannot be authentic. Rather, the scientific authenticity of an activity needs to be understood in terms of its relation to our experiences, and we need to focus on finding better ways to help making students' inquiry meaningful to be scientifically authentic.

Means of achieving scientific literacy. The NSES states the main goal is raising scientifically literate people who use science to make informed decisions on issues of personal and social import, so that our society becomes more intelligent and democratic.

Learning science concepts and scientific literacy. In order to raise scientifically literate people, who use science to make informed decisions on issues of personal and social import, the NSES includes the Content Standards with its key concepts and skills that students should know. It is assumed that students should have sound understanding of important science concepts to become responsible, scientifically literate citizens (Eisenhart et al., 1996). Relevant inquiry questions are suggested as motivators for learning science concepts (NRC, 2000). The NSES cautions that because students' questions often involve the complexity of real problems and stretch into other areas besides science, teachers need to guide students' questions into simple, testable ones so that they learn important science concepts and skills. In the same line of thought, Aldridge (1992) elaborated on the need to confine science activities as follows:

> Relevance may well be a key component of good motivation, but practical problems are often very complex, and variables identified are almost impossible to isolate or control. Student interest in personal or societal problems is highly individual, and group learning in a classroom setting appears very difficult. The range of problems, issues, and concerns could easily spread into areas beyond the natural sciences, leading to a blurring of distinctions in areas where such distinctions are very important, such as between science and technology, or between science and philosophy and religion. (Aldridge, 1992, p. 18)

Here, relevance is understood only as a motivator to learn science concepts rather than as a foundation to build scientific literacy. If relevance interferes with teaching science concepts or involves other disciplinary areas, teachers are advised against pursuing the question.

Issues of the content-driven approach to scientific literacy. Regarding learning and using science in socially responsible ways, Eisenhart and her colleagues (1998) argued that there are no empirical studies to support the link between acquiring scientific knowledge and using science in socially responsible ways. Although it is assumed that learning science concepts and the nature of science would benefit students in making informed decisions in scientific issues of society (NRC, 1996, 2000), there are studies showing that students' understanding of science concepts and the nature of science do not necessarily influence their judgment on socioscientific

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issues (Sadler, 2004). Rather, making a judgment is based on the interplay of personal experiences, social values, and ethics. Henriksen and Jorde (2001) have studied how museums provide relevant scientific information to help high school students make better judgments on radiation and environmental issues. Although the museum visits improved students' understanding in related science concepts, they didn't use their scientific understanding to make their personal judgments on the issues. In the study of the role of the nature of science in decision making on science- and technology-based issues, Bell and Lederman (2003) found that the participants didn't consider the nature of science much in making decisions. Rather, they based their decisions primarily on personal values, morals, and social concerns. In a survey of environmental science students' reasoning on socioscientific issues, Zeidler and Schafer (1984) determined that the level of science content knowledge does not influence students' judgment much. Rather, they made their judgment based on the context or the settings of the specific science issues. Henriksen and Jorde (2001) concluded that students don't use scientific understanding for decision making due to the lack of practice in making personal decisions on socioscientific issues.

Despite the need to allow students to make their own decisions based on their knowledge and experiences, Downey, Hegg, and Lucena (1993) found in their study that science and engineering students are channeled to focus on technical questions rather than to ask about personal concerns or societal needs regarding the scientific intervention. Students' personal or social questions are either weeded out or changed to find 'scientific' solutions in science and engineering education programs. As the result of such schooling, students change their reasoning depending on the classroom they are in. Saljo and Wyndhamn (1993) reported that students approach the same problem of fairness depending on which class they are in. If students are in a social study class, they take account of the social issues to judge fairness. If they are in math and

science class, they measure the quantity to judge fairness without considering the social issues. This kind of channeling of students' focus in order to teach science concepts obviously leads to a limited appreciation of the issue and does not lead to 'responsible use' of science in society.

These research findings are not surprising considering Crosthwaite's (2001) assertion, "Morality is particular and case specific and moral reflection is just a very close attention to details of a particular issue" (p. 102). Accordingly, scholars in the Science-Technology-Society movement or socioscientific issues movement have argued that educators need to pay attention to the moral dilemmas surrounding scientific issues to enable students to deal with scientific issues in society (Bybee, 1987; Sadler, 2004; Sadler & Zeidler, 2005). They argued that teaching only science concepts and not letting students use science to investigate their own concerns in school is like teaching only the property of ingredients without letting prospective chefs make any food, and then expecting they will all be able to cook wonderfully. This kind of practice leads students to participate in school science activity only to get school grades, instead of leading students to make informed decisions on scientific issues outside school (Eisenhart et al., 1996). In order to increase the ethical awareness of scientific issues to make informed decisions, Crosthwaite (2001) asserted that we need to let students practice ethical reflection and deliberation on socioscientific issues. Sadler (2004) and Andrew and Robottom (2001) also argued that students should be encouraged and have ample opportunities to think and talk about the moral values of socioscientific issues that are important to them, because when societal issues are not openly encouraged and discussed within science activities, they are likely to disappear in science learning practice. By considering the rights, benefits, authority, harm, power, and control of a particular socioscientific issue, students should discuss the interplay of scientific and ethical considerations and build frameworks for ethical deliberation (Crosthwaite, 2001).

In relation to the morality issue, the value of relevance in the content-centered approach of the NSES needs to be reconsidered. Different from what Aldridge (1992) and the NRC (2000)[6] seem to propose, investigating relevant topics is the key to achieve scientific literacy, not a disposable component to teach science. The NSES's standpoint may be reasonable within the current school structure where teachers' objectives and lesson plans are given higher priority than students' immediate interest and concerns. Yet, the lack of attention to students' interests and relevance costs a great deal in science education. Forty percent of students think science as a school subject is not relevant or important to their lives and they are not interested to learn science (Alberts, 2000). Students often do not see much social value in identifying themselves within school science and do not put much effort into learning and using scientific discourse (Carlone, 2004; Eisenhart et al., 1996).

Faced with this reality, science educators argue that we need to link students' experiences with science better to show the importance of science in their lives and to build their confidence in science. For example, Rosebery and her colleagues (1992) reported that a group of students complained that the water from the fountain near the kindergarten classrooms was bad due to the kindergarteners' germs, and they started to test the water quality of hallway fountains. The students found the question directly related to their school life and participated in the investigation with enthusiasm. Alberts (2000) argued that if students could only see the relevance of science to their lives, they would certainly be motivated to learn science. After reviewing

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[6] As I looked into the possible reasons of not explicitly encouraging students' pursuing inquiry questions of their personal and social needs, I noticed the NSES's statement about the nature of scientific inquiry is also problematic. It states, in contrast to engineering and technology, that the main purpose of scientific inquiry is to search for truth rather than to address personal or societal needs (Rudolph, 2005). The distinction contradicts the vision of scientific literacy in which people are to use science to address personal and social concerns. Also, the sociology of science shows that science, like other disciplines, advances in relation to the needs of society, and that personal concerns and social values pervade in scientific inquiry (Cunningham & Helms, 1998).

educational studies on socioscientific issues, Sadler (2004) concluded that when students see personal connections to the science topic, the lesson becomes most fruitful. For this matter, Dewey (1916/1980) asserted that our thinking develops as the learner acts to figure out relations in a situation that stimulates and poses a genuine, relevant problem.

Many critical pedagogy scholars and feminist science educators (e.g., Barton, 1998b; Davis, 2002; Fusco, 2001; Gayford, 1995; Gutierrez, Rymes, & Larson, 1995; Howes, 1998; Ladson-Billings, 1992) argued that investigating a personally, culturally relevant topic is crucial especially for minority students to "develop a sense of science as something that is important in their lives and their community outside of school" (Eisenhart et al., 1996, p. 284). For example, through investigating the deserted neighborhood of a homeless shelter (Barton, 1998a), children were able to find science as a tool to analyze their own situations and discuss the environmental issues of the neighborhood. Howes (1998) opened up a discussion on pregnancy and prenatal testing in science class to attend the urban high school girls' concerns through their own experiences and expertise. By doing such inquiries of their needs, interest, or expertise, those students participated in science learning with confidence, ownership, and enthusiasm.

The value of relevance in science inquiry should not be considered as sugar coating to motivate and teach science concepts to students. Rather, relevance is the central element of teaching science for scientific literacy. When students address their needs in school, they build the habit of using science for personal and social concerns. They also establish their identity within science so that they are able to envision themselves using science outside school walls (Eisenhart et al., 1996) The NSES's vision of scientific literacy can be realized only when students use science to solve their problems at school, rather than when students are suspending their experiences to learn science concepts for the future application. Dewey would agree that in order to become scientific literate, students should have the opportunity to investigate their

personal and social concerns in school and know when, why, and how to make scientific claims and value judgments. In *Experience and Education*, Dewey (1938/1988) believed that if we want our young to have a certain quality, we should help them practice the quality in school instead of blindly preparing for that quality. He wrote,

> We always live at the time we live and not at some other time, and only by extracting at each present time the full meaning of each present experience are we prepared for doing the same thing in the future. This is the only preparation which in the long run amounts to anything. All this means that attentive care must be devoted to the conditions which give each present experience a worth-while meaning. (Dewey, 1938/1988, pp. 29-30)

Explaining the futility of preparing for the future without attending to the present, Dewey (1938/1988) noted that we take the meaning out of each present experience and build future experiences accordingly. By focusing only on preparation for the future instead of on the meanings extracted from the present experience, we miss the potential of the present experience to be meaningful and relevant and thus to become useful resources for future action. Dewey (1916/1980) noted that if students do not see how learning functions to address their situations, it becomes an obligation and a burden rather than a means to enrich our life. Learning science should be part of our effort to understand and enrich ourselves and the society, rather than something we have to do.

The starting point to "give present experience a worthwhile meaning" (Dewey, 1938/1988, p. 49) for students is helping them investigate relevant questions of personal and social importance as they would do in their ordinary life or outside school. A study by Bouillion and Gomez (2001) illustrated this point well. Bouillion and Gomez (2001) investigated the effects of urban students' involvement in the self-identified problem of pollution of a nearby river. To address the situation, the students engaged in multiple activities, such as learning about pollution and ecosystems, testing the water, developing a conservancy plan, mobilizing community action for riverbank restoration and trash removal, and eventually working to secure

lease rights to the riverbank land. Investigating the real world problem was complex, but by bringing in community resources of scientists, parents, and community activists, the students successfully addressed the problem and made the project into a community action. Through participating in a problem of personal and social importance, students not only learned the relevant science concepts and skills, but they developed a sense of science as an important part of their lives as well as built their identity as participants of the scientific community. They also became interested in doing further community science projects and viewed themselves as important and competent members of society. The students in the study were able to participate in a scientific social activity and reflect on themselves in relation to the environment. In other words, the experience facilitated building scientific literacy that "enable[s] people to claim a place and voice in the world" (Eisenhart et al., 1996). When students are able to use science to address their concerns, see themselves in relation to science, and reflect on the moral aspect of the issue, students become responsible users of science.

Summary: Relevant scientific inquiry questions to build scientific literacy. I've explored one of NSES's definitions of inquiry in relation to scientific literacy and scientific authenticity. Based on Dewey's contextual authenticity of scientific inquiry, I showed that, in order to institute authentic scientific inquiry in school, we need to guide students to investigate relevant and meaningful problems at school, rather than focus on the procedural resemblance to scientists' practices or blindly teaching science concepts for later use. The relevant and meaningful inquiry questions are not just pretty wrappings to attract students to learn science concepts. Rather, I would argue that only when diverse students' experiences are included in science activities and the questions of individual and social import are pursued at school, they will be equipped to do the same thing as responsible, scientifically literate citizens in the future.

Manageable, developmentally appropriate questions. In this section, I explore the teaching standards of the NSES. The most significant element of teaching through inquiry is using developmentally appropriate topics so that students are able to grapple with the idea and build scientific explanations. The NSES notes that the teachers should guide students to be engaged in manageable problems that are appropriate to students' developmental levels. "The knowledge and procedures students use to answer the questions must be accessible and manageable, as well as appropriate to the students' developmental level" (NRC, 2000, p. 25). This developmentally appropriate curriculum is often emphasized to reach all students (NSTA, 1998). The importance of developmentally appropriate teaching practice is repeatedly mentioned in various educational documents, and many teachers pay much attention to the manageability of the tasks.

We feel frustrated when we face an overwhelmingly difficult situation and bored when we are given too an easy task. It seems natural to stress the importance of developmentally appropriate tasks so that students build understanding and confidence to solve problems. Dewey, likewise, emphasized constructing activity in harmony with the growth of the child's experience (Dewey, 1938/1988). He argued that teachers must strive to understand where the child is, what s/he is capable of, and what would be the most productive activity to produce the most beneficial learning experience. On the surface, Dewey and contemporary educational reformers are saying the same thing—developmentally appropriate tasks for students. Yet, there are certain differences between contemporary concepts of developmentally appropriateness and Dewey's (Tanner, 1997).

Developmentally appropriate topics. As we all know, we cannot expect toddlers to run before they are able to walk. Likewise, there are some concepts that require more scientific understanding than others. For example, we are expected to have a firm grasp of Newtonian

mechanics before delving into Einstein's relativity theory. Thus, for the inquiry topic, we often look for the logical sequence of science concepts to determine manageability of inquiry.

To help science teachers, the NSES lays out the scientific concepts based on the level of complexity. The Content Standards guide students to start from easy science concepts and then progress to more difficult ones. Because the scientific concepts in the Standards are logically arranged for students to master, the manageability or worth for students' learning is determined based on whether the concept is in the Standards or district curriculum (DeBoer, 2002). The NSES specifically indicates the importance of centering student's inquiry around the Content Standards: "[Student inquiry questions should directly] connect to the science concepts described in the Content Standards" (NRC, 2000, p. 24). It also recommends focusing on a few core ideas of science following the Standards in curriculum and eliminating "ideas that are not central to the development of science understanding" (NRC, 2007, p. 5). This means teachers need to sort out students' inquiry questions based on the Standards. If the inquiry topic is in the Content Standards, it's okay to encourage students to deal with it because the topic is probably appropriate for them. If the topic is not in the Standards, the teacher should discourage them from pursuing the question because the topic may lead into a meaningless or inappropriate inquiry.

In *The Child and the Curriculum*, Dewey (1902/1976a) recognized that educators often determine the curriculum mainly based on the logical sequence of the subject matter to make the topic 'manageable' for children. Such interpretation of "developmentally appropriate curriculum" is critiqued in terms of the diverse interactions of the inquirer and environment (Tanner, 1997). Dewey asserted that people construct meanings based on their interaction within the environment, and we cannot judge in advance how one topic would be perceived and pursued. Paley (1986) demonstrated with her kindergarten class stories that simple tasks in the eyes of the

teacher could be multilayered, complex problems in students' own minds and vice versa. The same topic may be approached quite differently depending on the situation an inquirer constructs. For example, on a winter morning water droplets on the windows may induce various kinds of inquiry. Some may enjoy drawing pictures on them and wonder how many pictures they could fit in. Others may wonder how to increase the fog in the window and try spraying water in the air. Some others may try to calculate the relative/absolute humidity and balance the evaporation/condensation equilibrium. Yet, for some other children, the phenomenon may not invoke a question at all. They may have more pressing questions to think about or they think they already know why it happens. The same phenomenon of water droplets on the windows results in different inquiries. The diversity of interactions or objectives illustrates that the topic itself cannot determine the difficulty or the quality of inquiry.

The centrality of the task has been criticized in relation to the Reader Response Theory. Freund (1987) observed that though people often regard that the text invokes a certain kind of reading, and literature scholars endeavor to find the objective meaning of the text, readers' interaction with the text is neither objective nor matches the authors' intentions. Rather, readers' experiences interact with the text to create new meanings. People's responses are not simply inscribed or controlled by the task itself. As in Dewey's ecological understanding of the world, reading of the text is the interplay of the reader's experiences and the text. This reader-response criticism deemphasizes the centrality of the task, and highlights the learner's experience to understand the context.

Not only might the same topic not yield the same inquiries, but the 'logical' sequence of topics may not be the best way to lead students to a better understanding of science. The fallacy of insisting on the sequence of the inquiry topics based on the grade level is well illustrated in the case study of Einstein. "As Einstein himself once said, he succeeded in good part because he

kept asking himself questions concerning space and time which only children wonder about"

(Holton, 1978, pp. 279: re-quoted from Gallas, 1995). Einstein succeeded not because he moved

from one topic to the next, following a well-planned curriculum, but because he persisted in

asking a question about his genuine interest even though the topic seemed childish. Instead of

dismissing the question as finished or inappropriate for a scientist, he went back to the same

topic again and again. He followed up the question with renewed understanding and persistency.

The insistency on the child-like question boosted his quality of inquiry and led to a greater

understanding. The Einstein case shows that the inquirer's involvement in the problem, rather

than the topic in itself, determines the quality of the inquiry.

As Dewey asserted, we interpret a situation within the boundary of our experiences. In

the abstract, there are neither absolutely difficult nor objectively appropriate topics for students.

Just because the topic is listed in the Content Standards, it shouldn't be automatically regarded

that the students will be engaged to learn the concepts in the same way and depth, nor that the

topic is 'developmentally appropriate,' 'worthwhile,' or 'fruitful' for them. Because the

interaction between the learner and the situation determines the manageability and the quality of

an inquiry, the developmentally appropriate topics should be understood as a negotiation

between the individual student's objectives and the subject matter (Dewey, 1902/1976a). Rather

than being preoccupied with the subject matter or the task itself, teachers should provide ample

opportunities for students to interact with the situation and strive to understand the interactions

(Dewey, 1916/1980, p. 183), that is, how the learner interprets the situation, how s/he goes about

it, and what s/he draws out of it. Understanding the interactions between learners, teacher,

activities, and other situational components are the starting points to guide students productively

(Dewey, 1902/1976a, 1938/1988).

Meaningful, engaging topics. The dynamic interaction between learners and the situation not only determines the difficulty of a task, but it also determines the level of engagement in the inquiry. For example, the importance or relevance of a problem to students' experiences plays a big part in how they engage with the situation, even with a difficult problem. Tanner (1988) referred to a study in which students faced difficulty reading maps and failed a simple maze test, but the same students successfully executed a rather difficult escape from the school's property using maps. The two tasks were similar in that both required the students to find a way out using maps. Yet, the first question was just a difficult task without any relevance to the students, whereas the other situation was the students' own problem—they needed to sneak out from the forbidden school property to avoid detention. As the students realized the importance and relevance of the task, they built a strategic plan and managed to solve the problem successfully. If the teacher only saw the maze test results, she would have thought the task was not developmentally appropriate for those students and lowered the level of difficulty, though the students clearly had the ability to get through a maze in real life. Gallas (1995) argued that the manageability of the question often depends on the way the question is brought into the science class rather than the topic itself. When students recognize the question invites their prior experiences and further exploration, they participate in the inquiry with enthusiasm, even on difficult topics. On the other hand, when students cannot relate to the context of the inquiry or misunderstand the question, it often leads to a lack of participation or frustration. As Appleton (2000) observed, "The capacity to learn and an emotional involvement in the subject matter cannot be separated" (p.142).

The NSES also states that investigating meaningful questions provides valuable learning opportunities and helps advance students' inquiry skills. The power of owning a problem is, however, interpreted as how to frame the given science topics in order for learners to feel

interested or improve their academic skills (NRC, 2000). Often, curriculum developers treat personal commitment and engagement as an "add-on feature" of the curriculum (Rieber, Smith, & Noah, 1998). I admit the skill to contextualize a question is important for teachers, especially when you have to work with a given curriculum. It helps to bridge the subject matter with students' experiences. It also aids teachers to get through the curriculum with more participation from the students. Dewey also mentioned psychologizing subject matter so that students see the alignment with their experience[7]. Yet, there is more to the relevance of inquiry to Dewey.

In the theory of inquiry, meaningfulness and relevance are the main attributes of inquiry, not the 'bells and whistles' to make inquiry attractive. Only when the problematic situation is real to the learner, like escaping from the school grounds, can we fully anticipate addressing the situation, and the inquiry runs its course despite the roadblocks. Only then, will it constitute a true inquiry. In contrast, when students cannot relate school subjects to the questions of their lives, it is not an inquiry but 'busy work', like the paper maze test. Because the whole process of inquiry is based on the learner's anticipation of the problematic situation, any irrelevant or meaningless task imposed by others is not regarded as inquiry in Dewey's theory of inquiry.

Dewey's persistent emphasis on meaningful, relevant inquiry should be understood not only as a teaching strategy of *how* to make the given topic attractive, but also as a teaching principle of choosing *what* to investigate in the first place. Dewey (1916/1980) argued that education should help students to reconstruct experiences for a fuller and meaningful life.

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[7] Here, Dewey's psychologizing is a little different from wrapping the subject matter in a pretty package. Rather, it is to understand the subject matter as flexible enough to be organized in different ways for different pedagogical purposes and for individual students. It also emphasizes subject matter as not fundamentally different from the knowledge already constructed by children. It is similarly fallible and subject to revision in response to lived experience. This means we no longer see the subject matter as something to be delivered, but rather as a map to guide experiences. The point is to experience life and make sense of those experiences, but not to appropriate the subject matter per se.

Because the subject matter from outside students' experiences is hollow, teachers should align

school activities with their experiences (Dewey, 1938/1988).

Educators, however, often focus on the difficulty of the task, not on the fundamental

question of what is worth to teach and learn for students' life (Tanner, 1997). What is the point to

discuss the difficulty of mindless, dead work? The schoolboys of Barbiana in *Letter to a Teacher*

(1970) clearly tell us this. Although the peasant boys tried to work hard at a public school, they

couldn't relate to the school work. Later, they put effort into researching their lives with help

from a minister to disclose the injustice of their society. They then charged the public schools for

shortchanging the kids by not teaching relevant things to their lives. Current educational

researchers (e.g., Noddings, 2006) lamented that our schools, so concerned with the standard

curriculum and limited by educational settings, do not provide the environments to learn about

the critical issues of our lives, such as self-understanding and forming and maintaining better

relationships with other people. Tanner (1997) argued,

> Schools need to be concerned about what is taught—its social value in a democratic
> society and worth to the child—as much as they are with whether children make too
> many errors because a problem or task is too difficult for them. (p. 7)

Developmentally appropriate, meaningful tasks. Dewey (1938/1991) argued that a

problem should always be understood in terms of its interaction within a learner's situation. The

degree of the endeavor to resolve the situation depends on the relevance of the question. When

we find the question relevant, we exert ourselves to address the problem despite difficulties. Yet,

our educators are often too concerned with the manageability of the task to reflect on the true

value of the meaningfulness of the inquiry. The difficulty of the task should be considered when

meaningfulness of the inquiry in student's life has been seriously considered. That way, the task

could work for students' growth not just as a busy work.

Manageable by whom? Who is the decision maker? Discussion of the difficulty and the relevance of inquiry leads to the question of who decides if a task is appropriate for the students. Traditionally it was entirely up to the teacher (or school district) to determine the content, select teaching materials, and organize the tasks because it was thought teachers are better equipped to make educational judgments than students. The teaching through inquiry approach, however, changes the role of the teacher from the directive knowledge transmitter to the facilitator or collaborator of students' learning. Sund and Trowbridge (1973) noted that the essence of inquiry-oriented teaching is arranging the learning environment and providing appropriate guidance to facilitate students' investigation in science. This inquiry approach promotes students' status from passive knowledge receiver to active meaning maker. The NSES (NRC, 2000) notes, "Effective learning requires that students take control of their own learning" (p. 119). This means the students' questions or experiences may steer the direction of class activities. Involving students' ideas and allowing their own inquiries means sometimes letting them contribute to the lesson planning. The degree of integration of students' ideas into curriculum varies—from changing the whole set of curriculum activities based on students' experiences, to allowing students to talk briefly about their ideas related to the topic of study. Nonetheless, teachers cannot fully determine the lesson in advance and need to be prepared to deviate from the original lesson plans if they are to incorporate students' ideas into instruction (Wiggins, 1989).

Issues of taking the new roles of teacher and students. New roles for teachers and students involve a shift in control of the classroom. Although teachers agree that the new role of students may help them take charge of their learning and develop knowledge better, teachers often feel uncomfortable, or even frustrated with the idea of letting go of the institutionalized

control over students' learning (R. D. Anderson & Helms, 2001; Barab & Luehmann, 2003; C. J. Burke, 2001).

First, teachers think that students lack preparation or the skills to take over the responsibility of their own learning (R. D. Anderson & Helms, 2001; Welch et al., 1981). Teachers feel that giving the control of learning to the students who are not familiar with scientific discourse would not work—because they would not know what to do, get frustrated, feel like they don't learn anything, and eventually, shut off from learning entirely. Rather, for those students, teachers feel that they need to direct the activities and give explicit instructions on how to perform science activities (Lee & Fradd, 1998).

Second, the transition of control to students requires a new level of teachers' managerial skills in class environments (Cohen, 1994; Jarrett, 1997; Welch et al., 1981). Huberman and Middlebrooks (2000) listed three risks entailed in inquiry-based science teaching: (a) losing control of the flow of a lesson and content area covered; (b) working with designs without known solutions; and (c) sacrificing familiar, well-oiled expertise for uncharted territories. What if a student's investigation is going completely off road, quite differently from what the teacher anticipated? What if a group of students want to investigate a problem that is not in the district curriculum? Or what if the teacher hasn't tried the inquiry topic before and doesn't know what's going to be involved or what kinds of learning resources are available for the activity? What if a group of students need more time for their inquiry when a new unit is supposed to start next week?

Third, the new role of teachers in inquiry education is not consistent with the school structure where authority and discipline are emphasized (Welch et al., 1981). The school structures are built around the traditional teacher-student relationship model. The teacher has socially legitimized authority over the curriculum and students (Ellsworth, 1989; Hogan & Corey,

2001). Because people believe it's the teacher's job to engage the students in learning, not the students themselves or their agency (R. P. McDermott, 1977; Walker, 1992), we think teachers need to design the class; teachers need to decide an appropriate teaching approach and the ways to connect the subject matter to students' experiences; and teachers need to evaluate and grade students' learning, not the students themselves. With the contemporary emphasis on the prescribed, standardized outcome of schooling, teachers are expected to follow diligently the state or district curriculum or suffer the consequences of bad test results (Wells, 2000). All these instructional practices at schools hamper the sharing of instructional control with the students.

In addition, students themselves are not accustomed to taking control of their own learning. While students welcome the responsibility of their learning when the circumstances are right (Wigginton, 1989), they are cautious about venturing into having their own voices heard in accordance with the teacher (Gutierrez et al., 1995). Students are use to the traditional passive role and resist taking on new responsibility (Barab & Luehmann, 2003; Lee & Fradd, 1998; Welch et al., 1981). Carlone (2004) reported that some students didn't participate actively because they were afraid of loosing their passive, good student identity. Other students dominated and excluded their peers when given the unaccustomed control of their learning (Cohen, 1994; King, 1993; Tobin, Seiler, & Walls, 1999; Yerrick, 1999). For example, King (1993) reported that students with higher academic status took over the group work even when the teacher assigned lower status students to leadership roles. Low achievers adopted the passivity model to save face, and their contributions had only minimal effects on the learning situation (King, 1993). Cohen (1994) explained that students compete for higher status in school, and lower status students are often cut off from accessing the resources of the group. As students build their positions in school and society, social norms or dynamics are incorporated into the interactions among the students themselves (Eckert, 1989).

Realizing the issues of responsibility and control, teachers have made an effort to build

learning environments for true communication and to understand the power dynamics through

reflexive teaching practices (Ellsworth, 1989; Osborne, 1998). Nevertheless, teachers "face the

dilemma of wanting students to become independent thinkers while not being able to resist the

urge to engineer their thinking toward the orthodoxy of ideas in a subject area" (J. L. Bencze,

2000, p. 849). Teachers have documented the difficulty of giving up telling students what to

think or do. Gallas (1995) confessed that teachers "are never prepared for the distress we feel

when we find we have to be quiet" (p. 18). It is true especially when students' discussion does

not reach the conclusion the teacher intended, and gentle nudges do not produce the desired

effect. Paley (1981, 1986) also noted the difficulty in "tapping into students' ideas" without

silencing their own voices. When she tried to guide her students' ideas at the 'teachable

moments', the students often regarded that the final word had been spoken on the issue and they

didn't chip in their ideas any more. Teaching in the school setting invariably involves a power

imbalance between teacher and student regardless of the teachers' orientation (R. P. McDermott,

1977). Researchers have called for teacher's flexible negotiation skills with students (Wells,

2000), broad knowledge in science and learning resources (Duckworth, 1987), and continuous

efforts to reflect on their teaching practices (Osborne, 1998) to navigate the challenging situation.

NSES's solutions to the role issues. Those issues raise questions of the role of teachers

and students. What does it mean to have learning environments for inquiry with shared authority

and new roles? What if the students' question does not deal with the topics in the Content

Standards or the inquiry seems too difficult for them? Who should take the responsibility for the

students' learning if the activity goes wrong?

Reflecting the reality of the school setting where teachers are perceived as responsible for

students' learning, the NSES focuses on the role of the teacher as the director or engineer of

students' inquiry rather than as a collaborator. The NSES (NRC, 2000) cautions that when

students pose inquiry questions, the teacher should *determine* if it's the right question for the

students[8] because "[n]ot all investigations that students propose will be worth pursuing" (p. 132).

First, teachers need to make sure the students' inquiry questions deal with the topics in the

national standards (Krajcik, Czerniak, & Berger, 1999, p. 68). Second, teachers need to make

sure that the students' inquiries lead to "empirical investigations" and they are "accessible and

manageable, as well as appropriate to the students' developmental level" (NRC, 2000, pp. 24-25).

That way, students are able to experience "fruitful scientific inquiries" at school. This common-

sense approach puts the teacher in charge of judging an appropriate question for the students.

This point is well illustrated throughout the document, *Inquiry and the National Science*

Education Standards. The only example[9] in which students brought their own questions into

science class illustrates how the teacher approved the question based on the preset curriculum

and carefully orchestrated the inquiry to be manageable and scientific (NRC, 2000, p. 6~10). The

NSES later added various techniques and examples to steer students' questions.

The NSES (NRC, 2000) also notes there are various degrees of student control in the

realm of teaching through inquiry—from very structured hands-on activities, to carefully guided

inquiry, to student-led open-ended inquiry. Students need not be engaged in student-led activities

to do an inquiry, and teachers need not allow students' control over the activity. Based on the

skill level of the students and the school environment, teachers choose how much control the

students may have. Only when the students are mature, skillful enough, may they conduct an

independent inquiry.

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[8] The NSES (NRC, 2000) states, "The teacher plays a critical role in guiding the identification of questions, particularly when they come from students" (p. 24).

[9] Other classroom inquiry examples show how the teachers were able to engage students in the inquiry process with the given topics instead of letting students bring their own questions into science class.

The NSES sends a mixed message about teacher and students' role over inquiry, and I find it problematic. With the strong emphasis on the Standards and high stakes testing, the teachers are bound to keep strong control over students' inquiry and follow the more teacher-directed model of inquiry rather than encouraging student-centered inquiry (DeBoer, 2002). When students are not actively encouraged to take charge of their learning, their contribution and commitment toward learning activities are minimal or accidental (Gutierrez et al., 1995). The tension between allowing students to conduct an inquiry in their own way and engineering students' inquiry is repeatedly shown in various examples in DeBoer's (2002) article. In one case, a science teacher wanted to involve the students in student-initiated inquiry projects. He set up the general content of the lessons and allowed the students to design scientific investigations based on their own interests. Yet, the teacher struggled with juggling between meeting the content standards and allowing the students' freedom. He ended up frequently stepping in to formulate students' inquiry questions and directing the investigation, in order to make sure the students' activity covered the contents in the curriculum and the investigation was scientific enough. In the end, the students felt frustrated with this approach, wondering how much freedom they actually had to pursue their own questions.

Dewey's vision of teacher and students' roles. Dewey also thought inquiry is a "complex, rigorous, intellectual, and emotional enterprise that takes time to do well" (Rodgers, 2002, p. 844). Dewey (1902/1976a) acknowledged that teachers need to guide the students' minds to connect with society's accumulated knowledge. Although he recognized the role of the teacher as a guide with more experience and knowledge, he didn't believe teachers should use their authority to determine what's right for the students. He would rather see students constructing a problematic situation for themselves regardless of the teacher's intention (see the example of a boring lecture hall in Chapter 2). He would argue for the need for students' collaboration with

the teacher in identifying and refining an inquiry question. He would also argue that the NSES guideline— "Skillful teachers help students focus their questions so that they can experience both interesting and productive investigations" (NRC, 2000, p. 25)— should be interpreted with the understanding of the teacher as collaborator rather than the director of a student's inquiry. There are multiple reasons why Dewey emphasized the students' taking active part in shaping their inquiry questions.

Students as the judge of their experiences. The relevance of students' experiences is the key to a meaningful inquiry, as argued in the previous section. Because students judge the relevance and make a link to their experiences, the decision on inquiry questions should naturally be the result of a dialogue between the students and the teacher. Todd DeStigter (2005) explained this point from his experience in an alternative high school for Latino students in Chicago. Considering their background, he chose *The House on Mango Street* (Cisneros, 1991). He thought the story would help the students reflect on their experiences as an ethnic minority living in a poor neighborhood. To the teacher's dismay, however, the students showed little interest in the story. After months of effort and disappointment, the teacher invited the students into the investigation of what had gone wrong with the lessons. To the teacher's surprise, the students didn't want to learn more about their neighborhood. They already heard so many stories like that. They rather wanted to learn about their own immediate concerns—family issues and baby rearing for a pregnant girl, immigration history for a recent immigrant, and fixing cars for a former juvenile delinquent. As the students investigated their own situations, they were engrossed in learning to read and write. DeStigter used this experience to illustrate a point in Dewey's (1916/1980) educational philosophy—there is no educational value in the abstract. Before the original activity was put in place, the teacher thought it was relevant and it would empower the students. But through interaction with the students, the activity turned out to be not

as meaningful to them as the teacher initially envisioned. Through listening and responding to what the students had to say, the teacher was able to launch a new activity that was more meaningful and conducive to learning.

The NSES (NRC, 2000) acknowledges the importance of relevance to students' experiences, "Fruitful inquiries evolve from questions that are meaningful and relevant to students" (p. 24). Without dialogue with the students about their needs and experiences, however, teachers often presume or essentialize students' experiences. The decisions on 'appropriate' topics, even by critical educators, often turn out to be nonresponsive to students' experiences. Duckworth (1987) argued that when students are given a chance, they choose questions that are challenging and appropriate for themselves to build a better understanding of the world. Dewey (1916/1980) wrote that when the students actively participate in deciding which topic to investigate, the inquiry gets aligned with the experiences of learners and help pull out the full meaning of the world. If the relevance of the question to students' experiences is the key component of inquiry, students' experiences should be valued as the *actual* starting point of inquiry. The students should be invited to say what's relevant to their experiences as collaborators of the lesson planning, instead of ending up as passive followers of the teacher's decisions.

Setting up inquiry goals as a progressive inquiry. We often find our inquiry has unexpected turns or results. A good example is the discovery of the shape of the benzene molecule by Kekulé. He was stumped by the strange combination of hydrogen and carbon in benzene. He was not able to explain the shape of the molecule with the then-traditional knowledge. Quite unexpectedly, away from the science lab, however, he dreamed (or saw a drawing of) snakes taking hold of one another's tail, suggesting the cyclic shape of carbon-carbon bonds. Although he anticipated building a model of benzene, he didn't expect to solve the

mystery from somewhere away from his lab or scientific texts. To tell my own tale, when I first started my dissertation, I wanted to write the success stories of inquiry science for diverse student groups. I didn't expect to write about Deweyan inquiry and the NSES. Yet, unanticipated events and turns happened in such a way and they led me here. Although we set out to do an inquiry in a certain way, no one knows for sure what will be involved in the process and what the result will be.

Dewey (1938/1991) wrote that the ends of inquiry cannot be fully determined at the outset of the inquiry—because if we can anticipate all the possibilities, it is not an indeterminate, puzzling situation at all. Sometimes we do not understand the full meaning of the inquiry until after time has passed, like what the reasons were for the economic hardship in my family 30 years ago or why a particular student was always making trouble. Garrison (2008, personal communication) wrote, "The ends of logic are achieved when we gather what belongs together, although they may not belong until after they are gathered." In our lives, we continuously redefine our ends and means to reflect on the changed experiences and environments. Thus, Dewey (1938/1991) wrote, "[T]he determining of a genuine problem is a progressive inquiry" (p. 112). An inquiry results from a complex web of experiences and environments, and defining the inquiry question is a progressive inquiry itself. The emerging quality of inquiry is not something that can be blocked: rather, it's the nature of human inquiry.

However, as shown in the guidelines for redirecting students' questions, the NSES assumes teachers should set out the end product of the inquiry for students and determine what's appropriate for the students at the beginning of an inquiry. Teachers may want to provide guidance for students to perform a better inquiry. Yet, judging what's appropriate or manageable at the onset of the inquiry poses a danger of denying the emerging quality of the inquiry. It not only blocks the students' minds from evaluating and adjusting to new situations, but it also

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denies the students the possibility of extracting the fuller meaning of the inquiry itself. Instead of judging the quality of the inquiry prematurely, teachers should endeavor to follow students' inquiry and find the real quality of their work through watchful eyes (Paley, 1986; Roosevelt, 1998; Wiggins, 1989). Dewey's emphasis on the teacher's role as an observer and listener of students' inquiry should be understood this way.

Students' growth in initiating inquiry. The goal of education is the growth in the individual's capacity to deal with problematic situations (Dewey, 1916/1980). Similarly, the vision of scientific literacy is to raise citizens who can participate in scientific inquiry and make intelligent decisions (NRC, 2000; Rutherford & Ahlgren, 1990). However, when the teacher holds the sole authority to decide what's right for the students, rejecting the possibility of shared inquiry with students, they wonder what the teacher wants rather than developing initiatives to evaluate the situation in their own terms (Noddings, 2006; Robertson, 1992). From such authoritarian school science, students might gather science information, but it does not lead them to build an active, confident self identity. As Osborne (2000) argued, doing science is more than following rules and mastering scientific information—it involves building one's role and identity in relation to scientific inquiry. In order for students to develop critical inquiry abilities and become genuine inquirers, they need to frame their purposes, evaluate the situation, select appropriate means, investigate their questions, and discover the consequences of their decisions (Dewey, 1916/1980, 1938/1988). The responsibility of identifying and shaping their own questions is a good start for students to learn how to evaluate their own desires and reflect on their actions within given circumstances. That way, students will be able to "develop advanced inquiry abilities and understand how scientific knowledge is pursued" (NRC, 2000, p. 36). I don't believe all students are equipped to select their own inquiry questions from the start.

However, believing that the students do not know better and the teacher has to do all the selection for them is to deprive them a chance to develop the crucial inquiry skills.

Self-directed learning is also beneficial to create new ways of knowing for the young. How often are we surprised by young learners' questions and learn new ways of understanding from them (Gallas, 1995)? A deviation from the conventional questions of school science may lead to a new way of approaching science, but we unintentionally shut down creative minds of the young and lose our chances to broaden their knowledge when we hastily judge their questions. Roosevelt (1998) wrote,

> No generation of adults has reached an acme of knowledge and understanding such that we can reasonably and responsibly suppose that the duty of children is first to master all that 'we' know before getting around to knowing anything for themselves. (p. 87)

Instead of trying to prematurely judge and mold students' minds within adults' frames, we should pay attention to children's ideas and encourage their initiatives in creating their own questions and understanding. That way, a school becomes a place for fresh ideas and students become collaborators of our effort to understand the world.

Summary: The role of teacher and students. The NSES asserts that students need to be invited to participate and be responsible for their learning. But in the matter of identifying what's appropriate and manageable for students' inquiry, it sends a mixed message of who takes charge of students' learning. Rather than encouraging collaborative efforts with students to make their inquiry meaningful and appropriate, the NSES seems to bestow the power of the instructional decision mostly on the teacher. The NSES's choice may be sensible considering that teachers find it hard to give up on their institutionalized power over students' learning.

Dewey's idea on the role of education, however, brings us back to think why we want our students to hold the responsibility over their own learning in the first place—to facilitate students' learning of science so that they truly appreciate the value of scientific inquiry and grow

up to be life-long inquirers. Because the principal goal of science education is scientific literacy,

building a collaborative relationship with students needs to become an essential, not peripheral,

part in the teaching of science. Dewey (1916/1980) asserted that school environments should

invite students to become active collaborators in the democratic community, and the teacher

should be a builder of a productive learning environment rather than a director of students'

learning. Myles Horton also urged, "The teacher's job is to get [students] talking about [their

own problems]…and to trust people to come up with the answers" (Morris, 1984, p. 142).

Horton and Freire (1991) added,

> The more people participate in the process of their own education, the more the people
> participate in the process of defining what kind of production to produce, and for what
> and why, the more the people participate in the development of their selves. The more the
> people become themselves, the better the democracy. (p. 145)

In order to build a productive, democratic learning environment for the young, Dewey

(1916/1980, 1938/1988) observed that, instead of relying on institutionalized, hierarchical

authority, teachers have to earn their right to teach the students by understanding students'

experiences; searching for ways to shape classroom experiences into educative ones; providing

environments to stimulate thinking; having sympathetic attitude toward learner's activities;

participating in an activity with the students; and trusting and taking account of the powers of the

young.

Summary of the analysis. In this chapter, I have examined the meaning of inquiry

according to the NSES using Dewey's theory of inquiry. The analysis revealed that despite good

intentions, the NSES provides a limited, sometimes misleading vision of inquiry-based teaching

and learning for the current school settings. This mixed message contributes to the difficulties of

including diverse students' experiences in learning, achieving students' scientific literacy, and

encouraging students' participation in science. Dewey's theory of inquiry presents a more

effective vision of what we want to achieve in inquiry-based education, and understanding the

theory will better guide our movement to implement inquiry-based education.

Chapter 4

Prairie Middle School

I conducted a year-long observation study at the Prairie Middle School, where science teachers were trying hard to build interactive learning environments with hands-on materials and a problem-solving approach. While students were completing assigned tasks, they were actually engaged in various kinds of inquiry. Using detailed descriptions of students' dialogues, I analyze students' interactions during a science learning activity—what situations students were involved in, and what meanings they drew out of the situation. It is arguable if this case is what contemporary science educators have in mind for inquiry-based science teaching; however, I chose this case to illustrate the dynamics of students' social, emotional, and intellectual interactions in relation to an academic task.

Contexts of Prairie Middle School

School environment. The Prairie Middle School is a public school in a university town in the Midwest with a population of 110,000 (U.S. Census Bureau, 2000). The school has 1,000 students in grades 6-8. About 50 percent of the students were categorized as low-income students and eligible for free or reduced-priced lunches. The students' performance scores in state-wide testing were a little below the state average for the selected student group in this study. The average class size was about 18 students.

The school hallway walls were filled with students' work. Students' drawings and posters caught a visitor's eyes. They provided information about various ecosystems, famous writers' lives, and international science inventions. Walking down the hallway, a visitor could see students sitting around laughing, or students talking in groups. Working and playing together, the students appeared to enjoy their time at school.

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The science teachers at the Prairie Middle School didn't follow any particular textbook for the curriculum. They had appropriated various lesson ideas from here and there over the years, adapted them to fit into their classes, and constructed a thematic curriculum with a variety of hands-on activities. For example, student activities for the ecology unit included a computer simulation game to balance ecological elements, a simple experiment to test the existence of microorganisms in soils, an analysis of owl pellets to construct an ecological web, and a game outside to simulate organisms' competition on common goods. Thess activities were usually followed by a class discussion, in which the teacher carefully invited and probed the students' ideas. The activities were fun and dealt with important concepts in ecology.

Mr. Keith's 8th grade science class

Teacher. Mr. Keith is a very confident and friendly teacher with 12 years of teaching experience in the school. He refers to himself as a 'big believer of hands-on science' and does a lot of science projects with his students. He also has coached the after-school Science Olympiad team. The Science Olympiads greatly influenced his teaching—many of individual projects in class were drawn from Science Olympiad assignments. He is not afraid to try new things in class and continuously modifies the lesson plans based on students' feedback. He often participates in professional development workshops and science teachers' conventions. People recognize him as an award-winning, hard-working, innovative, inquiry-oriented teacher.

Students. There were 20 friendly and "squirrelly" students in the classroom. While they were working on individual or group projects, they walked around, asked questions, compared their work, and chatted. The teacher didn't discourage such nonscience talk as long as they were making steady progress on their project and the volume was low. The teacher and I chose several focus students at the beginning of the year. I videotaped them throughout the school year and

interviewed them at the end of each semester. For this study, I describe three groups of students, who paired themselves for the activity.

European-American boys. Matt was a silent student. When he was required to present his understanding to the whole class, though, he explained the science concepts thoroughly and elaborately. He always stayed focused on the science projects or discussions in class. His science projects were quite well crafted: he spent hours preparing and testing them at home. He received an "A" for every assignment.

Jack was a close friend of Matt's but had a different disposition. He often shared his ideas with the teacher and other students without being asked. He didn't get perfect scores like Matt but seemed to enjoy most of the tasks in the science class.

European-American girls. Abby was a chubby, long-blond-haired girl who came to the classroom earlier than anybody else and talked about her day to the teacher before the class started. During class, she called out to the teacher to ask procedural questions every few minutes, but her voice was never heard in class discussion sessions.

Figure 3. Classroom at Prairie Middle School. This picture is processed to hide the identity of the students and the teacher.

Sharon was a very close friend of Abby's with whom she always grouped together to talk about their friends, teachers, and shopping. She, like Abby, didn't speak out at all during the whole class discussions. While she asked for Abby's help on various occasions, she didn't ask for the teacher's help.

African-American and Latino boys. Alex was the tallest in the class and wore sport shirts and his hair braided. Alex was often engaged in conversation with his friends. Before the bell rang, he goofed around with them near the classroom door; for group/individual work, he chatted with his partner or wandered around to talk with other friends. But Alex rarely spoke to the teacher. When Mr. Keith tried to help him out with his projects or prompt him to catch up with the pace, he just leaned back and let the teacher do the work, or he walked away from the table. Alex was the only one who got an F in the class.

Juan's most common posture in class was crouching over the table working on the project with an unhappy look on his face. He sat with the African-American students in the back, but he did not goof around with them in hallway or school yard. He often demanded the teacher's help with various projects. When the teacher praised Juan's successful bottle rocket in class, he got openly teased several times by his friends.

Science curriculum. The science curriculum was divided into four themes: (a) basic science measurement skills for the first quarter, (b) ecology/biology for the second, (c) chemistry for the third, and (d) mechanism/motions for the last quarter. Each theme was studied through various activities. At the end of each activity, the teacher checked what the students had learned from the activity through a test, a product, and a report.

Among the many activities I observed, I chose the owl pellet activity for my analysis. It was a part of the ecology-biology unit. During the unit, the class enjoyed a computer simulation game for 2 weeks to balance various ecosystems and to learn the importance of biodiversity. The

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students hoorayed and groaned as they watched the groups of animals and plants thrive or die out. The students had fun out in the school yard competing to catch imaginary fish and witnessing that the fish could not recover a quarter of the original number. At the conclusion of the ecology/biology unit, the owl pellet activity was introduced to teach the natural food chain as well as the prey's skeletal structure and the names of the bones. Each group of students dissected an owl pellet, sorted the bones of prey, and reassembled the skeletons. After turning in a piece of construction paper with a labeled and glued-on bone structure, the students took a test on the shape and the name of the bones.

Data collection at Prairie Middle School

Capturing the interactions of the students and the teacher. I visited the Mr. Keith's 8th grade science class twice a week during the 2001-02 school year. I attended 48 sessions with this particular group of students. During the whole class instruction, I sat in the back of the classroom and took field notes. For individual or group activities, I walked around the class and helped the students a little and talked with them. At first I felt awkward sitting around with the students, but the teacher and the students kindly included me in their conversations. A couple of months after I started my observation, I started videotaping a group each day with a PZM microphone and a video camera on a tripod. I collected 32 videos, most of which have been transcribed.

Capturing the students' conceptualization of science class. To understand the students' conceptualization of the activities, I conducted interviews with the focus students at the end of each semester. I tried to set up interviews with at least two students each time, mostly the group partners. Because the students tended to select their partner based on their friendship, the comfortable relationship between the students eased the tension of the interview session a little bit for all of us.

I usually started the interview by asking them to draw their projects on paper to remember and reflect on their learning in the science class. I also asked them to share any exciting moments during class. I prepared the initial questions, but the actual interview questions varied depending on the group dynamics.

The interviews were conducted in the science classroom during the lunch hour or after school. Each interview session lasted approximately 30 to 50 minutes. The interviews were video recorded and transcribed. Although the interview sessions were designed to get students' perspective on their participation in science activities, I found one or two 30-minute interview sessions were not sufficient to reach my goal. Because of this realization, I relied more on the class video clips and my informal interactions with the students. The students' direct reflection on their learning in the science classroom became secondary. More frequent interviews for students' reflection on their participation would have strengthened the study.

Analysis of Students' Interactions During Owl Pellet Activity

An owl pellet is a compact ball of the owl preys' fur and bones. Owls catch small animals and eat them whole. Owls cannot digest the bones and fur of the prey. They gather such indigestible things in the stomach and spit them out as a pellet. The pellet tells what an owl has eaten for last 24 hours. The ecologists collect and take apart owl pellets to analyze the ecosystems of the area. Like ecologists, the students measured the owl pellets, fingered through the pellets, separated the bones from fur, identified each bone in relation to the prey animals, reconstructed the skeleton of the prey, and tallied the kind and the number of the prey animals as a whole class.

Although science educators often praise the owl pellet activity as an alternative to the dissection of any live animals, the students were not thrilled to go through an owl pellet. They

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were disgusted by the idea of touching "what an owl puked" after watching a video on owl pellets. Some female students declared that they were never going to touch the pellets. However, most of the initial repulsion subsided as they found themselves peeling off a pellet and going through the fur and bones. Here and there, I was able to hear students exclaiming, "A tooth! I found a tooth! Look at the tooth!" or "Dang, this (bone) is so white!" or "Hey, this skull is broken!" The students compared the bones with others and discussed which bone was which.

The task of sorting out the bones from the piles of fur and labeling them required a lot of attention to fingertip sensations and careful looking through the piles. The students made slow progress in the activity, and some wearied of the repetitiveness of the task by the time they wrapped up the activity by gluing down the skeletons on a piece of paper. Because of the drag and unenthusiastic reaction to the activity, Mr. Keith reconsidered how to pursue the activity in the following year's curriculum.

I analyze how Jack and Matt, who were among the most successful students in class, negotiated the definition of the humerus, the upper arm bone. I question the meaning of the scientifically authentic interaction during science activities. The interactions in Abby and Sharon's group are focused on to show their reliance on the teacher's resourcefulness as the scientific authority in class. I also illustrate the videos of Alex and Juan's group to analyze how the students construct their identity during an academic task and how the identity interacts with students' participation in the activity.

Figure 4. Owl pellet and skeleton of prey.

Interactions of Matt, Jack, and Collin with an owl pellet

Scientific scrutiny and construction of a situation. During the owl pellet activity, Matt paired up with Jack and Collin, who were also successful students in the class. Matt's group didn't goof around or make loud chattering noises. They stayed focused to achieve the day's goal. They mainly conversed about task-related topics, and the group was able to make steady progress and finish the task on time. On the day I videotaped the group, Matt was unwrapping and sorting the bone packages so that Jack could arrange the bones and Collin could glue them on a black piece of paper.

> Collin: (arranging a bone on the black paper) It's like this, right? (to Jack) Like how it's on yours?
>
> Jack: (looking down at the paper) Yeah.
>
> Collin: (to Jack) Does it look like it goes right there?
>
> Matt: (reads the label of a bone package) Kumu, humerus.
>
> Jack: Humerus.
>
> Matt: (to Jack) What's a humerus or something?
>
> Jack: A humerus is like the upper arm, or lower arm, or whatever. I think it's the upper arm. (puts a finger onto the skeleton layout sheet on and off several times)
>
> Collin: (continues gluing a bone without looking up) The lower arm.
>
> Matt: (unwraps the bone package without looking at the layout sheet) I think it's the lower arm. Oh, well.
>
> Jack: Upper or lower? Oh, yeah, it's a lower arm. (glances at Matt) My bad. (raises the body to look at the layout sheet and check)

In this excerpt, Matt, Jack, and Collin were showing an example of group dynamics the teacher anticipated: While reconstructing the skeletal layout of an owl's prey, the students were casually using the bone names and locations to identify and arrange the bones. They were also expertly comparing the prey's skeleton with their own bone structure to make sure the layout of the

skeleton was correct. Through this process, the students were naturally learning the skeletal structures rather than memorizing the names mechanically. The students' discussion of the bone names and structures was amazing.

In the above excerpt, however, I noticed a moment of uncoordinated effort. When Matt asked about what a humerus was, Jack correctly guessed it's was the upper arm. He then indirectly encouraged Matt to look at the layout sheet the teacher provided (see Figure 5). Instead of taking a peek at the layout sheet, Matt moved on to opening another bone package. Collin chimed in to assert that a humerus was the lower arm and Matt agreed. Facing a counter opinion, Jack didn't pursue the matter further or refer to the bone layout sheet to check the claim. He quickly relented and said a humerus was indeed the lower arm.

Employing collaborative group work in a science class is designed to help students build the skills to manage information, coordinate their ideas, and reach a sensible scientific decision as a group. Watching their decision-making process, I wondered why Jack, Matt, and Collin cut
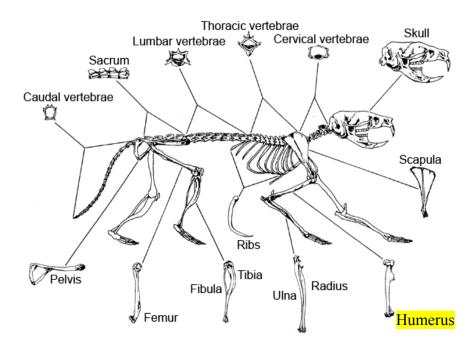

Figure 5. Layout of vole's skeleton.

the discussion short and didn't pursue the topic further to reach the right answer. They needed that information to reconstruct the skeleton. A clear reference point, the handout of a vole's skeletal structure, was on the table, right in front of them. Not only did the group mismanage the available information, they also didn't seem to care much about bringing their ideas together as a group. Matt just let the different idea stand without any deliberate effort to coordinate them. Because of careless and uncoordinated group interactions, those students failed to meet the educational objectives of collaborative group work, though they were generally successful in class.

Science educators would see the lack of close scrutiny and scientific discussion as a problem. "They've got a wrong answer!" "Aren't the students supposed to debate and examine their work more carefully like *real scientists*?" or "Why didn't the teacher explicitly guide those students on how to conduct a scientific inquiry so that they could emulate it?"

However, Mr. Keith did emphasize close examination of their work. He explicitly asked the whole class to refer to the layout sheet when the students were reconstructing the bones. He also walked around moderating the discussions and checking the quality of their work. If the teacher had been there at the moment, he could have steered the students to take a look at the layout sheet and helped them learn the name and location of the bone. Unfortunately for Matt's group, he did not check their progress at that moment.

Rather than trying to find fault with what the teacher did or didn't do for students' scientific examination on the skeletal structure, I questioned what the problematic situation was for each student at the moment. For Matt, obviously, the definition of a humerus was a part of his problematic situation, for he asked his group members for the definition. Yet, he was not fully engaged in getting the answer. He was aware there was only a limited amount of time left for the project. Anxious, he often urged his partners to speed up their work to finish on time. Following

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his own advice, he quickly chose the confident voice of Collin over an uncertain answer from Jack and moved on to open the bone packages, rather than taking time to search for the definition himself. Matt didn't linger on the issue, partly because he thought he got the right answer and partly because he sensed it was not as important as completing the project in time.

For Collin, the question didn't create much of a problematic situation. He had been gluing down the bones on black cardboard paper, continually complaining about the difficulty of the job. He was focusing all his attention on gluing the bones without making mess. With his hands full, Collin just chipped in his idea to respond to a hanging question rather than scrutinizing his answer.

Different from Matt and Collin, Jack was not so concerned about his task—arranging the bones for Collin to glue down. He was consciously balancing the group dynamics and trying to converse with his partners. When Matt asked the question, Jack paid attention, took his time, and gave his best answer. When faced with the convinced answer from his partners, however, he either lost confidence in his answer and gave in, or he overlooked their mistake and put down the bones in the right place anyway for Collin to glue down. Either way, he made a political decision to go with the flow and presented himself to be wrong about a humerus.

Examining the students' situations helps us to see better why the group reacted to the Matt's question that way. Collin and Matt were occupied with making progress with the task. Jack was wondering about the social consequences of his answer. As a result, they didn't seek the question as the teacher expected, not because they were unequipped to do so, but because they were not primarily focusing on knowing the definition of humerus at that moment. It was just not their main problematic situation.

Examining their interactions, I wondered how differently scientific researchers would have reacted to such situations. They are supposed to be better at examining the procedures and

results of their research (and professional ecologists surely know the definition of humerus). Yet, how critically do they deal with the quality of work done by their collaborators? How often do we dare to correct the minor details of work done by our coworkers? I doubt that practicing scientists would really make a big fuss about every detail, at the cost of conflicts and slower progress, unless the work is directly related to the central research questions or knowledge claims. Once a famous biologist reported that humans have 48 chromosomes (instead of 46); scientists after scientists confirmed that it was the right number, for over 30 years (Judson, 2008). Of course, the incident was entangled with technology developments as well as political aspects. However, this case shows scientists do miss things.

Scientific work is involved in various aspects of life. Scientists judge a knowledge claim not only based on the data itself, but also on how it fits with their existing knowledge scheme and who is making it. For example, although Pasteur's earlier model wasn't elaborate enough to explain Pouchet's data on life generation in a close-lid container after boiling, scientists found Pasteur's model fit better with their religious belief and accepted the famous experimenter Pasteur's theory over the Pouchet's model (McMullin, 1987).

If we consider the negotiation of values in scientific work, the commitment for precision becomes not an inherent trait of scientists, but the construction of a situation. If inquirers realize precision is a significant part of their research, they would make every effort to address the situation successfully—even if it involves debates with coworkers and slow progress toward the goals. If other factors outweigh the importance of precision in a particular step, inquirers may just go with the flow and focus on other things rather than facing conflicts or missing deadlines. If getting the correct definition of humerus had been the most important question for Matt, Jack, and Collin at that moment, they could have been involved in an inquiry of finding the meaning more thoroughly.

Many science educators expect to see the attitude of scientists during science activities, and often get disappointed when students display nonscientific attitudes as in the above episode. Yet, as I discussed, scientists themselves do not always show the 'model traits' throughout their work because they themselves are living in the web of human experiences. Instead of being scornful of the students for not being thorough in every part of their science activities, science educators need to understand that students are interacting with one another as well as with the learning materials. Without examining (a) what was the main problematic situation for students at a given moment; (b) why they recognized it as problematic; (c) how closely the students' situation was aligned with the teacher's planned activity; and (d) how authentically they are making an effort to address the problem, we may always remain disappointed with students' lack of 'scientific' aptitude.

Students' goal of the activity. As a measure to better understand students' construction of situation around the activity, I asked Matt and Jack about the activity during their lunch hour one day.

> Interviewer: I saw your group working very hard to finish that owl pellet thing. How did you like that activity?
>
> Matt: Oh, I didn't like it.
>
> Jack: It was hard, but it's kind [of] interesting to see what the bones look like of different animals, see like the size of them, and try to put them together. I thought it was pretty good.
>
> Matt: I thought it was very time consuming.
>
> Interviewer: Why?
>
> Matt: Well, just picking up the bones in the fur…It's tiring.
>
> Interviewer: Yes, but at first you liked it?
>
> Matt: It was okay, but 2 weeks…

Apparently, Jack was following the teacher's design of the activity. He liked such hands-on group work and enjoyed every phase of it. He thought picking out, sorting, and matching the bones was fun. He believed that he learned a lot about biodiversity and the food chain through the activity. Matt didn't see the value of the task like Jack. He thought the activity was uninformative. He stayed on task by exercising his patience.

While hands-on activities are generally designed for ooh-and-ah effects in the short term, activities in Mr. Keith's class usually lasted more than a couple of weeks and required persistence to complete them successfully. The teacher understood that science develops through enduring effort and craftsmanship. He intended to teach his students that science activities are not always fun and flashy: they sometimes could test their patience. However, I wonder if the activity was really helping the students realize what the teacher had in mind, considering the reason Matt was engaged in the activity—the grades.

> Interviewer: So what makes you keep on task even though it eventually is not very interesting?
>
> Matt: I think it's knowing that you are go[ing] to get a grade for it. So you just have to [keep] going.

Matt's reply may not be surprising, considering that Matt maintained the highest grades throughout the school year. Without a strong commitment toward a good grade, it must be hard to receive a perfect grade for every project at school. Anyway, don't we teach our kids to stay focused, do their work at school, and get good grades for their future, even when they don't like it at all? Yet, Matt's commitment toward a good grade, despite his dislike, reminded me of so many exhausted adults who burry themselves in work they don't care much about. They work in order to get money or maintain a social position rather than finding joy in their work. Matt was demonstrating such mentality toward the science project.

Although we need our children to learn what it takes to complete a task like a hard-working professional, using an external motivator is not what we want in education. Dewey (1938/1988) severely criticized schooling that diminishes the desire of learning rather than igniting it. Dewey declared that the main goal of education is to help students realize the impetus of learning by providing an opportunity to engage in a valuable activity. That way, students experience inner satisfaction through the activity and carry it on to further learning.

However, Mr. Keith didn't want to drag students along by the power of report cards, either. He strongly hoped that interesting hands-on activities, like the owl pellet activity, would naturally immerse students into science learning. Then, why did Matt recognize the science activity as one of the tedious, compulsory tasks for grades while Mr. Keith believed it was interesting for his students? Why didn't he see the activity the way Jack did?

To analyze the dilemma, I consider the meaning of 'interesting and educational' activities. To my mind, it is about successfully connecting student's experiences—not only the general academic desire to succeed in school but a more intimate connection to diverse learners' identities and experiences. Matt might have regarded the owl pellet activity differently if he had been deeply involved in saving an endangered species in the area, and this task could have served the cause; or if he had decided to become an owl expert or ecologist and wanted to get a first-hand experience. Such connections might have allowed him to recognize the task as an important learning opportunity and to get involved with much more vigor.

If personal connection is the key to "interesting activities" that invoke students' enjoyable involvement and build scientific minds, how could we draw learning activities from diverse students' experiences? If we encourage students to openly bring in inquiry topics to science class, would they really grab the chance and take charge of their inquiry? Students like Matt were silent in classroom discussions, indicating they were not eager to share their experiences with the

teacher or other classmates. It was not because the teacher was intimidating. On the contrary, the students didn't think it was their job to come up with possible topics for science activities. When I asked Matt and other students what they would like to do in science class, they vaguely said "fun stuff" without elaborating, despite a series of prompts. They were just not used to turning their experiences into inquiry activities in science class. In addition, the current curricular planning practice is not adequate to bring in students' real experiences into learning activities dynamically. Although Mr. Keith realized students were not nearly as enthusiastic about the activity as he envisioned, he wasn't able to drop the activity to accommodate individual students' needs. Even if he was able to construct a different activity, he needed to negotiate with the standards and the district curriculum to actually implement it.

Although educators often talk about the potential of meaningful activities for learning, there is quite a gap between the activities that teachers consider educational and those that students find appealing. In order to realize the power of 'interesting' activities, we need to consider the real connection of school activities to students' needs and evaluate the challenges of our instructional practices for both students and teachers.

Summary: Students' construction of problematic situation and scientific collaboration. While Matt, Jack, and Collin's group seemed collaboratively engaged in the task as the teacher anticipated, a close examination of their interaction revealed that they were constructing a different problematic situation than the teacher's. This should not be surprising considering that inquiry is drawn from the learner's goals, knowledge, and social interactions. Rather than scrutinizing students for not being scientific enough or trying to teach a certain aspect of scientific inquiry without appreciating the experiences of diverse learners, we need to understand how students actually construct an activity in relation to their needs and reexamine the challenges of our educational practices that prevent students from fully investigating their

questions with dedication. That way, learners could carry on a reflective, dedicated inquiry that would draw in true scientific components into the process (Dewey, 1938/1991).

Interactions of Abby and Sharon with an owl pellet

Sensitivity to cleanliness and participation in the activity. The difference between Abby and Sharon's reactions toward the owl pellet activity was quite apparent. Abby went through the fur in the pellet with her hands and didn't hesitate to hold the bones up close to her eyes. She proudly showed newly found bones to the teacher. On the other hand, Sharon was extremely annoyed that they had to touch "what an owl puked." She never touched the pellet with her hands. Instead, she used toothpicks to feel and peel fur off the bones, though that way was much harder and slower. The following excerpt shows how Sharon felt about the pellet.

Sharon: (peeling off the fur from a bone with toothpicks)

Abby: (touches Sharon's hair as if trying to get something off from the hair)

Sharon: (looking up) Did you touch my hair?

Abby: No, I didn't. (laughs)

Sharon: You touched my hair?

Abby: No.

Sharon: Who touched my hair?

Abby: (pulling up the sleeves) My elbow touched your hair.

Sharon: (resumes working with toothpicks)

Abby: (snorting laughs) I'm sorry.

Sharon: If you did touch my hair, I have to go home.

Abby: (picks up a bone and takes fur out from the bone) Why?

Sharon: To wash my hair, duh.

Abby: They wouldn't let you do that.

Sharon: Yes, they would. I would just tell them I was sick.

Sharon's repulsion toward the pellet was intense. Despite the fact that every pellet was chemically treated and safe to touch, Sharon didn't want to touch the pellet or to be remotely in contact with it. She even considered going home just because her friend touched her hair with her hand that had handled the pellet. Sharon was not alone in showing her distaste toward the owl pellet. Many other girls openly showed their disgust, without a moment's hesitation, but grudgingly participated in the activity. In U.S. society, girls are trained to be sensitive to cleanliness, and for those girls that sensitivity cost them enjoyment in the activity.

Their hygienic sensitivity, however, was not the only reason for their reluctance. When Sharon found a tooth in the pellet—a rare discovery, she got excited. She announced it to the whole class and her repulsion seemed to subside. She continuously talked about the tooth—the color, the place to put it, and the method to keep it from breakage. The small success in finding bones reduced her anxiety about cleanliness and helped her get much more involved in the activity. Sharon's attitude change indicates that her reluctance was not only caused by the ugly and smelly pellet. The lack of confidence in the task also contributed to her unwillingness. If she only had been more confident in science activities in general or known that she would be making a rare discovery in the activity, would she have acted the same? Confidence in science seems to be an important component to understand the students' mode of participation in learning activities at school. I explore how students formed confidence through the task in the next section.

Building confidence through the task. After Sharon got over her anxiety, the two partners started to discuss how to sort out the bones. The next excerpt shows how Sharon and Abby determined the name of the bone Sharon had found in the pellet.

Sharon: (drops a bone at a sorting chart and looks at Abby) What's this?

Abby: (looks down at the bone) It's a vertebra.

Sharon: Yes. (drops her head and searches for more bones).

Abby: (picks up the bone and shows it to the teacher who was helping the next group) What is this? There's a hole in the middle.

Teacher: (examines the bone and then look at Abby) That's a cervical. That's a very good example of cervical vertebrae.

When Sharon found a bone, she asked Abby about how she would classify the bone without offering her own idea. Abby informed Sharon that the bone was a vertebra. Agreeing with her, Sharon resumed finding bones in the pellet. Abby, on the other hand, didn't put the bone into the vertebrae pile and return to her work. Instead, she turned to the teacher to ask the same question that she had given an answer to. The teacher confirmed her initial assessment and provided more detailed classification for the bone. Abby, satisfied with the teacher's answer, turned back to the task. Throughout the day, this question-and-answer pattern repeated. Sharon asked Abby about various bones. Abby answered Sharon, but then she showed those bones to the teacher and asked the same question. Only when she got the teacher's answer to the question, did she move on to the next task.

This behavioral pattern could be due to the nature of their relationship. Sharon sought Abby's consultation on many aspects of teen life—like in a little sister and a big sister relationship. Abby constantly sought the teacher's attention and tried to involve him in every aspect of the class activity. Although Abby was capable of labeling the bones herself in the conversation with Sharon, she was acting as if she doesn't have a clue. She insistently called for the teacher, showed a newly found bone to him, and asked what kind of bone it was.

When Abby's act was combined with Sharon's reliance on Abby, the relay of "What's this?" question does not sound so innocent any more. It seemed to build up the stereotypical image of girls, who are more dependent and approval seeking than boys. The "What's this?"

question (rather than "Do you think this is X?") hides the questioner's own idea on the matter, and pushes the responsibility of knowing to the addressee. By asking the question without sharing their own ideas, both Sharon and Abby revealed that they were not confident enough to own their own ideas. They were operating under a knowledge hierarchy—the teacher at the top, Abby in the middle, and Sharon at the bottom.

There were differences in the frequency of asking for help among groups, but many students seemed to work under the knowledge hierarchy, expecting the teacher to give out quick answers for the project, like Abby and Sharon. The dependency on the teacher didn't seem to work to boost the students' confidence in performing the activities. Cognitive scientists (Ginsburg & Opper, 1969; Piaget, 1965) observed that the shift in the knowledge source from the teacher to students causes them to move away from an absolutistic understanding of the world toward a flexible, mutual knowledge construction. Contemporary science educators argue for adopting inquiry tasks to afford a better opportunity for students to build independent, scientific minds. Abby and Sharon's interaction shows they were not reflectively building communal knowledge through the task. Rather, they heavily relied on the teacher's knowledge, like a traditional didactic instruction.

Because I expected to see more dialogic discussions and more probing from a skillful teacher like Mr. Keith, I searched other videos of Abby and Sharon's group to find moments of a dynamic exchange of ideas. Instead, I found a clue to their reliance from an earlier session of the activity.

Abby: (to the teacher) What's this bone?

Mr. K: What do you think it is?

Abby: It looks like a humerus.

Mr. K: It's not a humerus.

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Sharon: It looks like that. (points at the bone sorting chart with a toothpick)

Mr. K: Notice how this really curves.

Sharon: It looks like that.

Mr. K: Actually, (points at the chart) it's same as this one right here. [tibia-fibula]

Abby: (points at the chart too) They don't have that little line [fibula].

Mr. K: Exactly. It's broken off the back. If you even look, you'll see where it's broken off.

Sharon and Abby: (silent)

Different from the previous episode, the teacher didn't give out the answer when Abby asked about a bone they found. He tried to guide them to find the answer by looking carefully at the bone. Sharon and Abby, however, didn't reach the answer he was looking for. They insisted on their initial wrong answer. After a few attempts, he reluctantly told the answer and explained how they could have identified the bone.

The video clip referred to above showed that the dependency is not because the teacher was giving out the answers to make the students dependent. He encouraged them to examine the bones closely and reach their own answers. They were simply not able to identify the bones like the teacher. Discussing among themselves didn't lead them to find the right answer either. They needed to rely on the teacher to complete the task successfully.

In a way, dependency on the knowledge hierarchy was due to the nature of the task rather than the lack of the teacher's encouragement or probing. While the overall task seemed to be heuristic, requiring students' own measures, the recognition and discrimination of the bones involved right-or-wrong answers. A bone was either a humerus or a tibia, not both. There was not much space for students' personal experience or creativity to play a role in recognizing the bones. To make matters worse, some bones were broken off and were not easily discernable

without an expert's eyes. For example, after debating whether a piece of bone was either a tooth or a kneecap for a while, a group of students showed the bone to the teacher. After a closer look, the teacher disappointingly concluded that it was just a broken piece of a bone. If the students decided the bone was a tooth or a kneecap rather than getting the teacher's answer, they might have some points taken off from their bone reconstruction project. Experiencing such incidents, students couldn't help but rely more on the teacher's judgment than their own for the bone identification. The students thus asked the teacher for help in identifying various bones. After meeting numerous demands, the teacher just gave out the answer to the students. Unfortunately, the activity was working like an action version of traditional worksheet, in which the teacher gives out the right answers as the authority of scientific knowledge and checks off the wrong answers.

In addition to the nature of the task, dependency seems to stem from the way the project was brought in. I asked a group of students what they would do if they didn't know how to proceed during a science activity. They told me they would go straight to Mr. Keith. They explained, "Because if he doesn't know about his project, nobody does." In this excerpt, I noticed their respect for Mr. Keith's scientific knowledge. He is indeed a knowledgeable, experienced teacher, and the students trusted his judgment. It is wonderful to be recognized as a resourceful teacher, for teaching and managing a classroom (Rowan & Bourne, 2001). Yet, I also noticed that they referred to the science project as *his* project, not their project. Although it was the students who were supposed to 'do the task', it was the teacher who set the task, its procedures, its goals, and its assessment standards. The task was assigned to the students, rather than derived from the students' own situations to solve a problematic situation (Dewey, 1938/1991). When we do a task set by another person, we naturally rely on that person's knowledge and seek to meet his or her expectations, rather than relying on our own. If we think

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that way, dependency on the teacher's knowledge was not simply due to the students' bad habit of relying on others without reflection. Rather, it seems to be partly due to the way the activity was presented to them.

While I was being critical of this scene, I realize that a hierarchical relationship of knowledge can be observed not only in science classes, but also in science fields and our everyday life. Novice scientists often seek their supervisor's approval of their results until they themselves become well-established researchers. Considering that it takes a long time and much effort for a novice scientist to become a seasoned researcher, it may be unreasonable to expect that just a few school activities would make students carry out science tasks independently. The problem I noticed from this scenario was not simply that students were unable to demonstrate independent thinking. I found it problematic because of the continuity of the experience. Students would not use that particular scientific knowledge in their future to progress into independent thinkers like novice scientists, but they would use the experience to rely on the scientific authority rather than to value their experiences and question the known.

Summary: Reflective participation and the nature of the task. Many contemporary researchers assert that when students' ideas and experiences are valued and incorporated in class activities, students, especially those who are traditionally marginalized, improve their participation in science learning activities (Davis, 2002; Gayford, 1995; Harberman, 1995; Rose, 1995; Roychoudhury, Tippins, & Nichols, 1993). However, many science learning tasks, like this owl pellet activity, are organized in a way unable to bring in students' experiences effectively and thus to encourage their involvement in productive, independent science learning. In order to help the growth of students' reflective minds, science educators need to devise better ways to align students' experiences with science activities.

Interactions of Alex and Juan with an owl pellet

Participation and marginalization. Since the owl pellet unit started, Alex drifted from group to group and talked to other students much more than usual. While Juan sat alone bending over the table and handling the bones, Alex went over to one group and another, chatting and laughing. When he was near his partner, Alex sat on the table and swung his legs, talking about his friends and other nonacademic topics. He seemed to be paying little attention to the task at hand. Sympathizing with Juan who had to work alone because of such an irresponsible partner, I videotaped the group to see how they were interacting with the activity. During the following conversation, Alex sat on the table and bent forward to look at the bones Juan had sorted out. Juan sat on the seat trying to glue down the bones.

> Alex: (reaches to the bones on the table) Dang, dude. That's…
>
> Juan: (hits Alex's hand, looking at him) Trying to do what, dude?
>
> Alex: I'm trying to work too. (tries to get a bone package)
>
> Juan: What are you go[ing] to do, man?
>
> Alex: (picks up a plastic bag with an extra skull instead)
>
> Juan: Ssss. (moves his arm as if he's going to hit Alex)

Alex tried to be a part of the group project by accessing the bones, but Juan overtly prevented him from touching the bones. Juan pointed out with a rhetorical question that Alex was not equipped to get involved in the task. Interestingly, Alex sought to contribute to the group work eight times during this particular class hour. Every time Juan rejected his offer of help. The rejection was sometimes explicit as shown in the excerpt—Juan's physical blocking Alex's access to the resources. Other times, Juan didn't even bother to respond to Alex when he asked if there was anything he could do to help. Because of such marginalization, Alex wasn't able to hold the bones except for only 4.5 minutes of the 30-minute video of the group. This short time

included 3.5 minutes in which Alex held an extra broken skull. This particular skull was not necessary to complete the layout of the skeleton, and Juan let Alex touch it.

In addition to limited access to the resources, Alex wasn't able to participate in the actual task-related work. While Juan was doing all the strategic tasks, such as sorting, laying out, and gluing down the bones, Alex was reduced to do a couple of small tasks, such as getting or returning materials and cutting out labels. Even when Juan complained that he had too much to do for this project, he didn't invite him to join in the task. Juan didn't regard Alex as a partner who could work with him. Alex was physically there, but Juan behaved as though Alex wasn't actually there for the group task.

If this activity had been a whole class demonstration, the students wouldn't have had such an issue with their access to the material. However, this activity was designed to provide the students a hands-on experience, in which they could observe, feel, and rebuild the bone structure. If a student had limited access to the material, s/he wouldn't be able to achieve the learning objectives. It was not very surprising to find that Alex didn't fully learn the related science concepts and had trouble discerning different kinds of bones by the end of this activity. How could he have learned the ways to discern one thing from another like other students when he wasn't able to participate in the task? He didn't learn much from the experience, and he was further impaired in contributing to the group work. The vicious cycle of rejection, not learning, and further rejection led Alex to lose interest in participating in school activities to learn science. He just roamed around the room to occupy himself by talking with friends. It was a disempowering, marginalizing experience for Alex (Hodges, 1998; Wenger, 1998).

Alex was not 'a science guy' in the class, and I knew that students during group work often exclude their partners based on their academic status (Cohen, 1994; King, 1993). Still, I didn't expect to see such overt marginalization during this activity because it was labor-intensive

(especially for sorting out bones from the owl pellet), and the students needed as many helping hands as they could get. Instead of complaining about his hard work, Juan could have included Alex and shared in the bone sorting. Yet, I realized Alex did play a role to create this dysfunctional partnership.

> Alex: (startled with a cracking sound as if a bone had broken under his arm)
>
> Juan: (raises the head to look at Alex) Ah, so you broke it?
>
> Alex: (sits up a little bit) No, I didn't *broke* it.
>
> Juan: (examines the bones closely).
>
> Alex: (picks up a couple of bones and a toothpick. puts some glue on the toothpick as if trying to glue the bones)
>
> Juan: (turns to Alex) Ah, don't do that.
>
> Alex: Ah.
>
> Juan: He already knows we've got two animals.
>
> Alex: I know…

Clumsily Alex broke a bone that Juan had carefully fished out from the pellet. Juan was not pleased to find it cracked by his partner. Keeping every bone intact was important to reconstruct

Figure 6. Alex and Juan during the owl pellet activity.

the skeleton. Juan was concerned that his clumsy partner might ruin the project by breaking more bones. In addition, Alex was an irresponsible partner who didn't care much about the project or the grade. When Juan asked about the location of the extra skull he had played with, Alex said, "I don't know. Don't ask me." He didn't even try to look for the skull. Instead, he just walked away from the table. Furthermore, Alex didn't know the name of the bones and wasn't able to distinguish them. He always received the lowest grade in the class. Considering all of Alex's negative aspects, Juan was unlucky to have a partner like him. "You have to have the right partner," some students complained to me. If Juan had had the 'right' partner, he wouldn't have had to exclude his partner or do all the work by himself.

It was regrettable that Alex and Juan each felt their partner was hard to work with. As a result, they weren't able to learn collaborative behaviors to work harmoniously and become dependable future citizens in a democratic society (Dewey, 1916/1980). The failure of their social development also prevented them from acquiring productive inquiry practices. Dewey (1938/1991) observed that collaboration is one of the main features of reflective inquiry. Contemporary science educators agree that most scientific inquiry is conducted in relation to other scientists and nonscientists, and students need to experience collaboration themselves first at school to understand the nature of scientific inquiry. Although Alex and Juan eventually succeeded in completing the final product, by excluding and being excluded from the task, they failed to achieve another major learning objective of the activity—to experience the collaborative nature of productive inquiry: why scientific inquirers collaborate, what is involved in scientific collaboration, and how to collaborate in scientific tasks. Unfortunately they only learned the competitive, exclusive side of scientific inquiry.

Marginalization and product grade. Because I noticed that Alex and Juan became friendly when they talked about nonacademic subjects, such as cars they would buy or sports

they played, I looked at how the task changed the students' interactions, rather than blaming the students' individual characters for the dysfunctional group dynamics. The sociable relationship lasted as long as Alex didn't attempt to participate in the task. The conflict seemed to arise in the process of completing the task.

In the activity many students didn't think respect and collaboration with their partners were as important as the product. They recognized that their main inquiry question was procedural—how to complete the project correctly. In order to achieve the goal, they often sought the teacher's confirmation on their progress and rejected any alternative approach. When they found a mistake by their partners, they severely scrutinized it. Low-achieving students often got the blame for ruining the project. After the repeated scrutiny of their mistakes, they worried they might make errors or break the bones to ruin the project. Because they couldn't commit themselves to the task, they focused on nonscientific activities in class, such as building social networks and trying to entertain their partners to keep their social relations intact.

The students' task-oriented behaviors were natural, considering that they were mainly evaluated by their final product—restoration of the bone layout. In these students' minds, the task was about making a good final product as the teacher guided them, not about collaborating harmoniously or creatively. Although the teacher didn't want the students to value only the product, he did use the product grade to push the students. He was concerned that if he didn't enforce the project with a grade, only a few science-oriented students would do their best, while the others would play around and learn nothing.

After watching Alex and Juan's group, however, I started to doubt that a product grade would really help those less-motivated students to participate in group activities. Cohen (1994) found that students tend to focus on the product instead of the collaborative process, especially when the group work is product-oriented. They often exhibit exclusion and manipulation of their

partners in order to get the job done their way (King, 1993). When the final product is emphasized, high-achieving students naturally dominate the group dynamics because they believe they are better equipped to make presentable products, and low achievers lose ground as an equal partner. In the process, students don't think spontaneous negotiation and equitable collaboration is essential in completing such tasks, and the lower-achieving students are at risk for being marginalized from learning science (Cohen, 1994).

Science education researchers often claim that assigning collaborative group activities would benefit traditionally marginalized students (Davis, 2002; Gayford, 1995; Roychoudhury et al., 1993). Although the activity itself had some components of collaborative group work, the focus on a pre-set product seems to have limited the possibility of true collaboration and failed to include the marginalized students and their voices.

Another turn of marginalization. Considering that the teacher introduced the group activity in part to teach the value of collaborative inquiry, I investigated how the marginalizing relationship manifested with the teacher's presence, hoping the teacher would successfully buffer the conflict and include Alex in the activity. Actually Mr. Keith paid frequent visits to Alex and Juan's group. When Juan asked for help, Mr. Keith would stroll toward the group, sit next to Juan, and start working on the project. He would sort out the bones, listen to Juan's questions, and suggest what to do. While Mr. Keith and Juan talked about the sorting and gluing of the bones, Alex stood across the table, twiddled a bone, and listened silently.

Juan: (looking at the bone the teacher is sorting out) Is that a bone?

Mr. Keith: Here's a cervical. That would be the first one you could glue down. (puts down the bone on the black paper)

Juan: Oh-ho. (looks at the bone closely and picks it up) Should I just lay it down flat?

Mr. Keith: Ye[s], lay it flat.

Juan: Or 3D?

Mr. Keith: You could try to do it 3D. But I'm telling you, it's kind of hard.

Juan: I'll do it flat then. (looks at the teacher) Should I glue it down now?

Mr. Keith: (nods) Ye[s], you can go ahead and glue it down there.

Juan: (puts some glues on the paper)

Mr. Keith: Here's a lumbar. (drops a bone on the black paper)

Juan: What?

Mr. Keith: Lumbar vertebrae. (looks into bones)

Juan: (looks carefully at the bones on the black paper) What's a lumbar?

Mr. Keith: Uh, lower back.

Juan: (puts glue on the paper)

In the conversation, the change in group dynamics is apparent. Rather than physical shoving, Juan was showing the pattern of Abby, Sharon, and Mr. Keith's discussion—where students were asking a series of procedural questions and the teacher was kindly answering them. However, the pattern was different from Abby and Sharon's group: only Juan was talking with Mr. Keith, as if this group consisted of only himself and Mr. Keith. Juan kept asking the teacher questions, eager to make progress on the task. Meanwhile, Alex looked at what Juan and Mr. Keith were doing, without saying anything. He sat on the table and idly swung his legs.

The change in the dynamics seemed to be due to the sudden prevalence of task-related interactions. Rather than lecturing Alex to work on the project, Mr. Keith was leading the task-oriented discussions in order to show Alex he could ask questions and contribute to the task. It was his way of encouraging students' participation indirectly. The teacher's intervention to the group backfired, however. Rather than bringing in Alex to the procedural decision-making process, it silenced the dialogue between Juan and Alex for social networking. The main

speakers of the group became Juan and Mr. Keith, and Alex became more peripheral than before.

Instead of feeling invited to the task, Alex must have felt that he was completely ignored by both

Juan and the teacher. He decided to challenge the new group dynamic.

Juan: (to the teacher) Hey, so, could we just put the thoracic all together?

Alex: (suddenly sitting up) Hey, what are you talking [about], smartest stuff?

Juan: (looks at Alex) Who?

Alex: (points at Juan) *You*.

Juan: (turns to the teacher)

Alex: (softly) What's a thoracic? (looks at the bone sorting chart on the table)

T: (to Juan) You just lay them together in the order that you have on that sheet.

Juan: All right.

Alex: (starts to sing while swinging his legs but still looking at the bone location sheet)

Juan: Put some glue on them?

T: (drops a bone carefully on the sorting chart) Here is a nice thoracic.

Juan: Should we put glue on them?

T: Ah, put glue…You can glue down here if you want, and then lay them in glue. But before you get too far, let me see if I can find a cervical for you, at least one or two, and some more tail.

Juan: (looks at the bones) Should I lay down the glue?

T: Ye[s]. You may do [it]. And put this over. (drops a bone on the paper)

Alex: (walks away singing)

Juan and T: (continue working without looking up to see Alex walk away)

By asking Juan a rhetorical question why he was trying so hard to act smart in front of the

teacher, Alex obviously attempted to alter the dynamic. His intention could be interpreted in a

two ways: (a) He might have been trying to stop the academic discussion between Juan and the

teacher because he was not part of it. During the dyad, Juan blocked his participation in the task,

but he was at least interacting with him. He wanted Juan back to talk about 'stuff'; or (b) it might have been Alex's way of confessing that he didn't exactly understand what's going on with the task, but he wanted to be part of the activity. After Juan turned to the teacher, Alex hesitantly admitted his desire to learn about the name of the bone and searched the information on the chart. He had been fiddling with the bones ever since the activity started, despite Juan's explicit disapproval, and watching the interactions between Juan and the teacher might have motivated him to do something to be part of the academic task. Either way, the blunt question was Alex's attempt to be included in the conversation with Juan.

His challenge, however, was unsuccessful. Maybe Alex should have known that such a lame attempt would not succeed, considering his steady marginalization by Juan. For Juan, successfully completing the task was his prime concern, not deciphering his partner's intents or emotions. He might have thought Alex was envious of his knowledge, but he didn't dwell on it. He turned his back to Alex, burying Alex's question with his procedural ones. Alex lingered at the table, possibly to figure out about the thoracic or to wait for a response from Juan or the teacher. Listening to the discussion between Juan and Mr. Keith for a few moments more, Alex realized he didn't have a place in the group after all and left the table. By leaving, Alex seemed to be giving up on participating in the task. Previously, it was Juan who drew the boundaries between them, and Alex was the one who sought to cross the line to the center of the activity. Now that the challenge had failed, Alex gave up on entering center stage, leaving for a separate place from Juan, physically and conceptually.

Dysfunctional partnership and the goal of school education. There could be many what-ifs for this unfortunate situation. What if Mr. Keith had heard Alex's question about the thoracic? Couldn't it have been a teachable moment to bring Alex into the task to become a legitimate participant rather than a nonparticipant?

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But Mr. Keith was too busy helping Juan progress with the task to grab that chance. He knew he wouldn't be able to afford for the students to proceed at their own paces. How well could we prepare teaching materials and ensure safety when students are engaged in different activities in a small classroom? Like many other teachers, he had to move all students along to the next activity in accordance to the curriculum. There are so many things they needed to learn, like chemistry and physics, and we don't want students stuck in an ecology unit all year long.

It is not clear how much Mr. Keith could have done to help fix the relationship if he had heard what was going on between Alex and Juan. Mr. Keith had found Alex singing and talking with his friends without doing his work before. He had told Alex to stop goofing off and participate in the class activity. He had personally escorted him into his seat. Rather than changing his behavior, Alex recognized the teacher as a person to stay away from. Mr. Keith hadn't been able to build a casual relationship with him like he had with the other students.

Students often think it is a waste of time to listen to lectures on how they should interact with one another (Hu, 2009).

> [S]ome students complain that the school has no business dictating what they wear or how they act in their personal lives. Others say that no matter what is taught in the classroom, there is a different reality in [their lives]. (para. 6)

Typically, teachers feel that they should focus on achieving academic goals, not students' social relations. While educational researchers call our attention to teach students explicitly on how to work collaboratively (Cohen, 1994), others argue against the teaching of nonacademic matters at school, such as values or social relations, because it would "crowd out the academic mission of our schools" (Hu, 2009 para. 10). In addition, just adding a couple of slots for teaching values without students' involvement won't achieve anything (Tanner, 1997).

From those commonly shared sentiments, I notice how schooling is framed as separate from our daily life or how we live our lives. In class, students are asked to investigate a skeletal

structure and how it explains our body movement, but not the structures and dynamics of their family, friends, and social networks. Science teachers are to teach the physical collision of balls or cars, but not about how to resolve our conflicts with other people. Teachers are to encourage students to discuss the socio-ethical aspects of cloning and environmental issues, but not of student groups and bullying at school. Teachers are to keep pace with academic tasks, but not with students' social and emotional development.

Although we all say that science education reforms or inquiry-based teaching is about bringing in students' experiences to school and helping them reflect on their experiences to improve their lives, we are teaching them the distinction between scientific, intellectual topics and students' everyday problems— 'Participating in school science activity is about explaining the natural world outside us. Schooling is not about assisting you to reflect on real everyday experiences or the world you are living in. You're on your own to figure out how to live your daily lives.'

Summary: Marginalization and integration of moral education for science learning.
Alex, Juan, and Mr. Keith's interaction illustrates how students' social relationship is entangled with their participation and learning of science. In the current school environment, however, moral education remains peripheral. Students' real concerns are set aside to investigate scientific topics or to listen to teachers lecture on how to behave in some imaginary cases—may be because both students and teachers are uncomfortable in dealing openly with real concerns in class, and because the current structure of school focuses on a limited sense of academic achievement and does not support such dialogue intermingled with an academic project. We know from experience that just assigning a couple of periods to teach moral values is not likely to influence students' moral development. Students wouldn't change their actions just because the teacher told them to. Ethical and social growth requires students' own reflective inquiries,

negotiation with various dilemmas, navigation through their actual circumstances, and realization of the consequences of their actions. Alex and Juan needed to understand the meaning of their actions and learn to participate in collaborative activities better. Unfortunately, creating environments for such reflective inquiry at school seems quite a challenge, and we are often more than happy to dismiss value education as a family matter.

Owl pellet activity on the component checklist

Relevance. While Mr. Keith tried to incorporate students' experiences by asking students' feedback on class activities, there were only limited ways to reflect students' voices, values, interests, and cultures in the science activities. This particular activity, for example, was chosen not because it was directly related to the students' experiences, but because it was suitable to teach 'science.' When students started the project, the unusual hands-on materials made them excited. As it progressed, the students' interest in the pellet activity slowly faded. Although the activity by its nature was related to the ecological issues of our society, none of the focus students understood it as relevant to their daily lives. The activity was an artificial learning task and they were just simulating a biological investigation. The students thought they stayed on task for a good grade, rather than to investigate important environmental issues. If the context had been different, students might have been able to link the activity to their experiences better— such as, if the activity was executed as a collaboration project with a group of real ecologists who were studying some problems of the local forests; if the pellets were brought in to investigate their own issues; if the students were allowed to investigate the pellet anyway they wanted; or if the teacher and the students at least had fully discussed the meaning of their work before the activity.

The important point is that introducing a hands-on science activity may provide excitement to students, but it does not automatically make it meaningful. Even if the task has

some relevance to the students' environment, it may not be relevant enough to initiate an inquiry for the students. Without careful examination of students' problematic situations (not only conceptual but their situation as a whole) and how they could investigate the issue with a systematic inquiry in class, a science learning activity may end up as an 'as usual' school task with no direct connection to students' lives.

Participation. Despite some heuristic nature of the task, the task was framed as a close-ended problem that required following the teacher's protocol. The students didn't have the expertise or initiatives to lead the activity in a different way. Mr. Keith often suspended his ideas and tried to guide students to build their own ideas, but when difficulty arose, they mostly relied on him to get the right answers rather than to discuss the problem among themselves. The students knew the ultimate judge of the activity was the teacher. Because of its academic product orientation, the task didn't particularly lead the historically marginalized students into participation. They were sometimes denied access to the learning material by their partners, and the teacher did not closely monitor their participation or intervene. While students' social development played an important role in building their identities, social networks, and scientific knowledge, there was no mechanism to openly bring in their social and emotional concerns in the middle of an academic task to improve their participation in the activity. Rather than leaving Alex with a label as useless or a failure, and Juan as uncooperative, we need to first keep in mind that students' intellectual growth needs to be accompanied by their social and emotional growth. Then we would be one step closer to constructing a better learning environment to encourage students' own reflective inquiries for successful navigation of their social and intellectual dilemmas.

Significance. As the wrap-up task for the ecology unit, the students investigated the characteristics and contents of the owl pellets, the mammal's skeletal structure, and techniques of

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bone identification and classification. A thorough examination of the pellets might have taught them that ecologists' work involves some craftsmanship and some repetitive labors like any other human endeavors. Although some students might have reached those academic objectives of the project, it unfortunately didn't lead them to reflect in depth on their everyday experiences or to participate in a further inquiry along the line of an ecological investigation of the neighborhood. I don't believe the teacher considered this aspect as the goal of this activity—as many schools do not consider the increased awareness of their experiences or active participation in outside school investigations as the prime goal of science class. My evaluation of the owl pellet activity seems to boil down to the question: What are our educational objectives as we argue for scientific literacy for our students?

Inquiry component triangle. The inquiry component triangle (see Figure 7) for the owl pellet activity is drawn much bigger than traditional didactic lectures, for it encouraged the students' active interaction with the materials, ideas, and their partners. However, the activity was not directly related to a significant problem of students but an artificial simulation of ecologists' work. Due to the way the task was set up, the students' collaborative relationship with one another was not fully developed. Although the students might have learned related science concepts, it's questionable how they would use them for their lives outside school. Because of these issues, the activity doesn't have high scores for the inquiry component triangle.
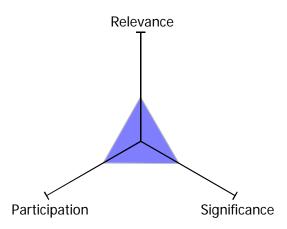
Figure 7. Inquiry component triangle for Prairie Middle School.

Chapter 5

Dewey's Chicago Laboratory School

Contexts of Dewey's Chicago Laboratory School

The Laboratory School in Dewey's theory. Many Deweyan scholars agree that the

Laboratory School was Dewey's most significant work (Benson, Harkavy, & Puckett, 2007). His

experience at the school served as the basis for him to establish many of his ideas on education

and philosophy. While at the Chicago Laboratory School, Dewey wrote *The School and Society*

(1900/1976), and *The Child and the Curriculum* (1902/1976a). He explicitly credited the

teachers there for developing the ideas in *How We Think* (1933/1986) and *Democracy and*

Education (1916/1980).

As the head of the Departments of Philosophy, Psychology, and Pedagogy at the

University of Chicago, John Dewey established an experimental school in 1896. Based on his

experiences as a school boy, a prominent scholar, and a father of three young children, he

ambitiously started the school (Tanner, 1997). He directed the operation of the school with Ella

Flagg Young as the supervisor of instruction and Alice Dewey as the principal (Mayhew &

Edwards, 1936/1965). After 6 years of operation, however, Dewey left the Lab School and the

University in 1904. With his departure, the school turned from its innovative, experimental

approach to teaching (Mayhew & Edwards, 1936/1965).

As the name suggested, Dewey envisioned the main purpose of the school to be a

laboratory of pedagogy where educators could test and build scientific theories of education

through practice (Jackson, 1990). The school was neither for providing immediate strategies for

teaching nor for training teachers (Lagemann, 2000). Rather, it was to "discover and apply the

principles that govern all human development that is truly educative, to utilize the methods by

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which mankind has collectively and progressively advanced in skill, understanding, and associated life" (Mayhew & Edwards, 1936/1965, p. 6). By doing so, Dewey hoped to merge educational practice with pedagogical, psychological scholarship. The teachers of the Laboratory School confessed the school fell short of putting its ideals into most successful practices (Mayhew & Edwards, 1936/1965). However, the practices at the school provide invaluable insights on today's educational problems (Tanner, 1997).

Based on its significance to Dewey's philosophy and its unique role as a laboratory for educational theories, I included Dewey's Laboratory School in my research. Interestingly, the records of the school show the teachers faced challenges strikingly similar to contemporary educators, yet took quite different approaches in some aspects (Tanner, 1997). Especially for encouraging students' social development, Dewey and the teachers established a unique collaborative learning environment. Below, I explore how the collaborative school community encouraged students' inquiry and how it came short of embodying Dewey's revolutionary educational visions.

Historical contexts of the Chicago Laboratory School

Social environments of Chicago in the 1890s. In the late 1890s and early 1900s, Chicago was growing rapidly as the hub of railways and ports, connecting cities to the East and West. Naturally, the manufacturing and retail businesses flourished. Due to its industrial success, the population grew from less than 300,000 in 1870 to 1.7 million in 1900 (Paral & Norkewicz, 2003). The new Chicagoans were mostly from rural communities and Europe. Along with the rapid growth of the city, the public schools expanded quickly to have 250,000 students by 1900 (Rury, 2005). There remained a significant number of private and parochial schools to serve German immigrants, who wanted to have instruction in their native language, and Irish and other Catholics, who protested reading the Protestant Bible in public schools (Rury, 2005).

Chicago had several labor movements in late 1800s that ended up in bloody conflicts, arrests, and executions. The Haymarket Affair and the Pullman Strike are the most publicized incidents in 1880-90s. The newspapers illustrated the polarized public reactions toward those incidents, and Chicagoans feared the escalating tensions between workers and company owners, and between ethnic groups.

As the number of foreign-born students expanded and social conflicts were evident, the public school boards tried to assimilate the immigrant workmen's children to "American life" by putting more emphasis on the study of history and civic responsibility "to teach loyalty, love of country, and devotion to American principles and institutions" (Rury, 2005). In contrast to the assimilation effort through instruction on responsibility, Jane Addams moved to live among the socially marginalized people and argued that we needed first to understand the situation and work with them to help build a better society (Hamington, 2007). She worked for immigrants and poor laborers through the social settlement movement at Hull House and provided education for thousands of people, utilizing the surrounding sociohistorical issues and industrial materials (Rury, 2005).

Jane Addams' work strongly influenced many of his important ideas on education, democracy, and philosophy, and John Dewey frequently visited Hull House even before he moved to Chicago (Hamington, 2007). Witnessing the growing divided society and the work at Hull House, he believed schools should contribute in building an inclusive, cohesive, and collaborative society (Lagemann, 2000). For this educational purpose, Dewey envisioned the Lab School as a miniature cooperative society, beyond social divisions, so that children could develop habits for a more democratic social life (Mayhew & Edwards, 1936/1965).

Indeed, the collaboration among different people was one of the founding ideas of the Lab School (Mayhew & Edwards, 1936/1965). Dewey believed collaboration with different

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people would provide productive experiences for school members to develop intellectual

autonomy and democratic relations. He actively prompted the Lab School faculty and students to

seek partnerships with different people. The administrative staff and teachers worked together as

a team for teaching, developing and evaluating educational plans for the school. The school

faculty collaborated with many of the University of Chicago faculty for material and intellectual

resources. The parents helped the school not only financially, but also intellectually through

frequent communication with the school staff. The teachers believed such collaboration would

enrich their teaching practices and help the students to build a more democratic society beyond

the wall of occupational divisions (Tanner, 1997).

   The Chicago Laboratory School in the 1890s. In late 1890s, the conditions of the

Chicago public schools were pitiable—overcrowded classes in basements, not enough desks and

benches, and limited school supplies (Rury, 2005). As a place for educational experimentations,

Dewey wanted to keep the Lab School in particularly favorable conditions for teaching and

learning despite financial difficulties (Jackson, 1990). In order to provide sufficient individual

attention to the students, the school kept a relatively low pupil-teacher ratio, about 9 or 10 to 1

(Mayhew & Edwards, 1936/1965). When the school opened in January 1896, it had 16 children

and two teachers. With the support from the families and friends, by 1902 the number increased

to 140 students and 23 teachers with 10 assistants (Mayhew & Edwards, 1936/1965).The school

was supplemented with adequate teaching/learning materials. The classrooms were structured to

allow participatory group projects, and the University supplied abundant intellectual resources.

The school had its own garden and playground outside.

   The families of the students were generally supportive of the school's effort (Mayhew &

Edwards, 1936/1965), providing material and intellectual resources for the curriculum as well as

financial assistance. When the families doubted the educational value of the school's approach,

Dewey endeavored to facilitate communication between the school staff and the parents, and he also offered a university course for the parents (Tanner, 1997).

The teachers at the Lab School were highly qualified and dedicated (Jackson, 1990). They were accordingly respected for their intellectual work. "To discover the conditions under which educative growth actually occurs" (Mayhew & Edwards, 1936/1965, p. 6), the teachers were given ample opportunities and time to experiment and reflect on their teaching rather than being inspected or dictated to on how to teach children. The school administrators collaborated with the teachers, as partners, for planning, executing, and evaluating the lessons (Tanner, 1997). Dewey believed that a hierarchical relationship was not productive, especially for educational practices. He thought that teachers' instructional freedom and intellectual collaboration with others would ensure effective teaching much better than hierarchical distribution of teaching methods—from university scholars to school administrators and to teachers (Lagemann, 2000).

Overall, the school operated as a collaborative community (Tanner, 1997). The relationship between the students and the teachers, between the teachers and the supervisors, and between the teachers and the parents, was reflective, and included participatory collaborations, aiming to improve the education of children. The students also felt that they had a share in the activities at school and their own work to do. This collaborative relationship was intentionally put forth to generate a collective force for better education and to develop a collaborative, autonomous disposition in the students (Tanner, 1997).

Analysis of Textile Occupations Project

Analytical methods. Examining the possibilities and limitations of the instructional practice at the Lab School is challenging because it operated a 100 years ago and had a different historical, cultural context than ours. However, the Lab School teachers, historians, and

educational researchers have studied the school records and made the information available. I examine the activities at the Lab School based on major scholarly reports, such as *The Dewey School: The Laboratory School of the University of Chicago 1896-1903* (Mayhew & Edwards, 1936/1965), *Dewey's Laboratory School: Lessons for Today* (Tanner, 1997), and *Dewey's Dream: Universities and Democracies in an Age of Education Reform* (Benson et al., 2007).

The teachers at the Lab School wrote *The Dewey School: The Laboratory School of the University of Chicago 1896-1903*, and described how the lessons were designed and carried out based on their experiences and school records. One of the authors was the head of the science department and taught the textile unit for Group IX, which I chose for this study. *Dewey's Laboratory School: Lessons for Today* comprehensively analyzed the curriculum and the class dynamics in relation to Dewey's theory and contemporary educational issues, such as the interdisciplinary curriculum and the role of teachers and students. *Dewey's Dream: Universities and Democracies in an Age of Education Reform* showed how Dewey's ideal school as a democratic social center was realized in the Lab School in relation to a school-community partnership.

Activities at Dewey's Lab School. After many years of trial, the school curriculum was organized around the various domestic and social occupations in the history of economic development of American society (Mayhew & Edwards, 1936/1965). This curriculum appealed to Dewey and the teachers because it was interdisciplinary, integrating intellectual, emotional, moral, and behavioral aspects. Students studied domestic occupations in early colonial days in the lower grades, such as cooking and farming, and progressed to the inventions and discoveries of European colonists, and on to industrial development of the then-modern times.

The main theme for the 7th grade curriculum (12 year-olds in Group IX) was the study of colonists and the industrial development of the textile industry: from domestically making

clothes, to selling/buying clothes for profit, to the separation of merchants and manufacturers, and to the emergence of the textile factory. To study the historical evolution of the textile industry, students re-enacted the entire process of making cloth in preindustrial times. They collected the raw materials (e.g., sheep's wool), constructed a wooden spindle and loom, spun the material into yarn, dyed the yarn, and wove it into cloth of their own design (Mayhew & Edwards, 1936/1965) (see Figure 8).

Through enacting the historical process of cloth making, the students realized their methods were similar to their ancestors' and understood better the circumstances and the problems involved in cloth making in the past. Building the necessary equipment and going through the whole process of making cloth, the students learned the value of collaboration with others, the fruit of manual labor, and the power of science, as well as various occupations and historical facts. This study should not be regarded as a vocational training by any means. Dewey was critical of making education into vocational training, believing "the latter would aggravate

Figure 8. Classroom at Dewey's Lab School. Students are spinning and dyeing wool. This picture was retrieved from the University of Chicago Laboratory School's website.

the class differences by sorting out students into the privileged who received a liberal education, and the lower classes, trained only for a particular task" (Boisvert, 1998, p. 100).

Relevance

Studying occupations as an interdisciplinary theme. The textile industry project integrated various disciplines, such as history, chemistry, physics, economics, art, and carpentry. For economics, students investigated how people traded the cloth and made a living; for physics, they observed the mechanism and efficiency of looms; for chemistry, they learned the composition and function of soap and dye; and for art, they observed how colors and designs created beautiful cloth. The integration of various subject areas came from Dewey's observation that any real world problem is interdisciplinary and that good judgments come from well-rounded knowledge.

Different from common conceptions, Dewey regarded that we perceive the world holistically, and the subject areas are adopted only for convenience of analysis. Dewey (1900/1976) wrote, "All studies arise from aspects of the one earth and the one life lived upon it. We do not have a series of stratified earths, one of which is mathematical, another physical, another historical, and so on" (p. 54). Criticizing how schools tried to teach students to see the world through the lens of separate subject matters, Dewey (1900/1976) urged, "Relate the school to life, and all studies are of necessity correlated" (p. 55). Because all subject matter is naturally interrelated, students need to participate in interdisciplinary units in order to see how scientific knowledge is integrated into everyday life (W. M. Roth, 2007).

Despite Dewey's call for teaching the interdisciplinary nature of real-world problems, it is questionable how the activities at the Lab School were fulfilling the call. Granted, the project had various activities, but they sounded like a conglomeration of separate tasks without a close relation to students' real-life problems. Dewey's insistence on interdisciplinary activities came

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from his belief that schools should bring in real-life problems for genuine learning and that they are interdisciplinary by nature. Just putting together a series of activities doesn't make the project a real-world or interdisciplinary problem. It needs to have a unifying goal of addressing real-life problems that students truly care about. The textile industry project was not really dealing with what was going on in students' households or in the society, and it was not likely that the students needed to know how to use a loom for their living. The project was derived mainly from a series of academic challenges that Dewey and the teachers thought of, similar to its contemporary counterparts (Benson et al., 2007). The uncertainty of how the project connected to students' outside-school experiences and how the students owned the problem is quite disappointing, considering that relevance was one of Dewey's central educational assertions. Next, I explore why he failed to design a project that addressed students' everyday problems that existed beyond school walls.

Simulating life outside versus solving real problems. Mayhew and Edwards (1936/1965) described that the teachers at the Lab School had tried to connect school activities with the students' daily experience so that they could use the experience for their daily life. In *The School and Society* (1900/1976) as well as in many of his other writings, Dewey insisted on the intimate connection between school and students' life outside school. As schools are social institutions responsible for forming future citizens through meaningful learning, Dewey asserted that schools should bring the students' experiences from outside school into classroom so they could really live, find joy in their endeavors, cultivate the desire of learning, and overcome the gap between the school and home. Tanner (1997) wrote, "Dewey tried to tie the curriculum to reality so that it did not go spinning off by itself as an isolated world existing only in the school's rarefied atmosphere" (p. 38).

Despite the fact that Dewey and the teachers wanted to build the curriculum based on students' daily experiences, the occupations curriculum didn't seem to really connect to the students' lives. Why did they choose activities that were unrelated to solving the students or the community's real-life problems, such as investigating the social divisions of that time and helping Jane Addams with immigration workers, or investigating the workings of the then-contemporary textile industry? In addition, why did they plan activities with known solutions? Didn't Dewey say students' intelligence develops when they engage in a challenging inquiry and face the consequences of their actions? Where were the real challenges? What were the consequences beyond the school walls? How could this simulated problem without real challenges or consequences be able to prepare students to take real-life challenges in the future?

Dewey regarded school as a simplified social environment. Although he argued that school education should help students extract fuller meaning from their (outside school) experiences, he also thought schools needed to offer children a simplified social life so that they could gradually get familiar with the social life.

> This simplified social life should reproduce, in miniature, the activities fundamental to life as a whole, and thus enable the child, on one side, to become gradually acquainted with the structure, materials, and modes of operation of the larger community; while, upon the other, it enables him individually to express himself through these lines of conduct, and thus attain control of his own powers. (Dewey, 1896/1972b, p. 438)

Gradually immersing themselves into a complicated social life would mean removing some components of real-life problems for the students. Although introducing a simplified social life was intended to help students understand the workings of the society better, it unfortunately filtered the reality out of it (Benson et al., 2007). As a result, the activities did not connect the students' real experiences and they were left with simulating life outside school rather than investigating it, like many contemporary students. Thus, the Lab School became "an unnatural, artificial university laboratory isolated from American life" (Benson et al., 2007, p. 31).

At the same time, however, Dewey criticized the rhetoric of education as preparation for the future. He charged that the 'old education' model disregarded the importance of students' current experiences under the name of preparation for the future. He asserted that students could be prepared for the future only by investigating their experiences and extracting full meanings from the situation. In one of his most frequently quoted passages, he argued that if we'd like to have our students intellectually engage in real life problems in the future, we need to guide them to investigate their real problems reflectively and collaboratively at school rather than blindly teach them a series of simulated problems for the future.

> We always live at the time we live and not at some other time, and only by extracting at each present time the full meaning of each present experience are we prepared for doing the same thing in the future. This is the only preparation which in the long run amounts to anything. All this means that attentive care must be devoted to the conditions which give each present experience a worthwhile meaning. (Dewey, 1938/1988, pp. 29-30)

The discrepancy might have been because Dewey and the teachers weren't able to move beyond the idea of school as a contained learning center (Benson et al., 2007). They didn't have access to the concept of contemporary community-based learning projects. Dewey was caught between making students' inquiry drawn from their real experiences and gradually building up their intelligence. He resolved that the real problems for learning need not come from students' experiences outside school life but from their interactions at school. In the next section, I further discuss how Dewey and the teachers used students' interactions within school as grounds for learning activities.

Participation

Miniature collaborative community. Dewey made every effort to establish a collaborative community at the Chicago Lab School. The issues facing the industrial society were increasingly obvious in Chicago in the late 1890s and early 1900s. Watching the growing social divisions, Dewey believed schools should contribute to building a collaborative,

democratic society by eliminating undemocratic features from school environments and including various social groups in school activities. That way, students would have opportunities to share their common interests and learn the benefits of a collaborative community (Boisvert, 1998).

Dewey thus encouraged collaborative participation from all school members and reconfigured the relationship between students and teachers, between school administrators and teachers, between teachers and parents, and among students (Tanner, 1997). Teachers, parents, administrators, university faculty members, and students put school activities and materials in place through collaboration. When a teacher planned or reflected on a curricular activity, fellow teachers and administrators contributed their ideas as colleagues on a regular basis. The students also had a share in lesson planning. Students and teachers continuously discussed together the aims and directions of lessons. When the lessons were not going as originally planned, they changed the operation of the lessons collaboratively (Mayhew & Edwards, 1936/1965). For example, a while after the new school year started, one teacher found many students lacked the skills of reading and writing to proceed with the planned activities. Rather than going ahead with the original plan, the teacher discussed this matter with the students and other teachers. The students agreed that they could not go on as planned until they were able to read the books they needed to complete their project. They decided to set aside sufficient time to practice reading and writing in relation to the curricular task, an action reflecting that the curriculum was not set firmly at the beginning of school year. Rather, it was a set of goals continuously negotiated and modified through dialogue with various school members.

Dewey (1938/1991) believed our knowing is derived from our interaction with the environment, and it cannot be separated from the way we live and act in the world. Because he emphasized the participatory nature of learning, he argued that schools, like other organizations,

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should encourage students to participate in activities as valuable members. Such participatory

interaction would afford students opportunities to express themselves actively, explore their

surroundings, negotiate their ideas, and thus develop intellectual vigor and character (Tanner,

1997). Mayhew and Edwards wrote,

> It was thought that education could prepare the young for future social life only when the school was itself a cooperative society on a small scale. The integration of the individual and society is impossible except when the individual lives in close association with others in the constant and free give and take of experiences and finds his happiness and growth in processes of sharing with them. (Mayhew & Edwards, 1936/1965, p. 466)

Such collaborative relationships were put in place in order for the students not only to *learn*

about the value of collaboration. It was also for them to *experience* collaborative relationships

and constructively *use* the experiences to grow. Even though explicit moral education might have

not happened during such interactions at the Lab School, Dewey believed in the integration of

intellectual and social learning, and character education permeated a large part of the curriculum

and school life (Tanner, 1997). The conversations through collaborative relationships were

adopted as a valuable tool to teach values and develop social intelligence in students. In a sense,

Dewey recognized that building the school environments to encourage such collaborative,

interactive learning was an effective way to bridge the gap between students' experiences and

school learning. Dewey's approach of developing character through dialogue with various

members of the school provides a stark contrast to contemporary moral education.

     Individual students' interest and effort. Although most of the students participated well

in the project, students' participation in curriculum planning didn't always result in the same

enthusiasm for the activities. Mayhew and Edwards remembered a few boys in that particular

class who were not completely engaged in the activities.

> The year's program was carried through successfully with the majority of the children in Group IX. There were in this group, however, and in several of the older groups a number of boys who were irked by the historical approach and who seemed to require a

shift in method. Their interests were not in line with those of the rest of the children; their attention was divided or entirely lacking; and their efforts, in accord with their interest, either retarded or interfered with those the others. (Mayhew & Edwards, 1936/1965, pp. 213-214)

Rather than forcing the students' compliance to the curriculum by disciplinary acts or failing grades, the teachers made the necessary accommodations to allow those students to conduct individual tasks based on their own interests. The teachers took them out to find their interests, diverted from their original lesson plans, and guided them to develop their own individualized projects. Mayhew and Edwards reported,

These boys were finally taken out of the class and allowed to follow their own diverse and individual lines until the general trend of their interests could be determined. This interest proved to be along scientific lines closely related to things the boys were making in the shop such as pile-drivers, heat engines, or the simple surveying and navigating instruments of the early discoverers and inventors. (Mayhew & Edwards, 1936/1965, p. 214)

Providing the students such individual attention must have complicated the lesson planning and operation for the teachers. Many contemporary educators would rightly credit the extraordinary circumstances of the Dewey's Lab School for accommodating such individualized projects—the high ratio of teacher to students; highly qualified teachers; and abundant intellectual and material resources from the university.

We also need to acknowledge that the effort was aligned with Dewey's (1938/1991) understanding of students' diverse construction of a situation. Because students would inevitably engage in different inquiries based on their experiences, he asserted that teachers need to encourage them to find their own ways to explore and connect with the materials. If teachers insist on a single way of participation in activities despite the diversity of experiences, they are destined to fail in providing an educative experience for all students. In addition, if students are to become genuine inquirers, they have to investigate their questions and discover the consequences of their decisions rather than wonder what the teacher wants (Noddings, 2006;

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Robertson, 1992). Thus, Dewey (1916/1980) urged teachers to listen sympathetically to students' desires and encourage their own approach to make school learning productive.

Such understanding of students' individualized learning may sound obsolete considering the fact that contemporary educational discourse often views individualized or customized learning as betraying the equity in the standardized testing environments. Although the boys at the Dewey's Lab School were not physically doing the same thing as the rest of the class, we wouldn't say they were treated unequally. First of all, the boys were not deprived of the chance to participate in the group project. Rather, they were given the choice to redirect their energy to a productive learning experience. They were able to understand and pursue their interests. As they independently directed their inquiry to test out their ideas and solve the problems in the process, they gained some measure of control of their interests and efforts (Lagemann, 2000; Mayhew & Edwards, 1936/1965; Tanner, 1997). Rather than becoming outcasts or labeled troublemakers, they were included as valuable resources to the class. They thrived through individualized learning. In this sense, we should not mechanically regard equality the same as students physically doing the same thing. Even from a seemingly same task, learners extract different meanings and engage in different inquiries based on their experiences (Dewey, 1938/1991). Shouldn't we think of equality as providing an equal opportunity for students to follow their heart's desire and learn from the experience, as Noddings (2006) asserts?

Significance. The school environment as a democratic collaborative community was one of the most characteristic features at Dewey's Lab School. As students were learning about the development of their industrial society, they experienced wide-ranging collaborations, expressed their ideas freely, and collaboratively participated in projects. Through the interactions, they built independence, confidence, and collaborative attitudes. Display of their initiatives and perseverance often surprised others. One alumna commented,

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It is difficult for me to be restrained about the character building results of the Dewey School. As the years have passed and as I have watched the lives of many Dewey School children, I have always been astonished at the ease which fits them into all sorts and conditions of emergencies. They do not vacillate and flounder under unstable emotions; they go ahead and work out the problem in hand, guided by their positively formed working habits. (Mayhew & Edwards, 1936/1965, p. 406)

It was a remarkable achievement attained through careful attention to students' character development, but I wonder what kinds of situations the students were prepared to deal with through their education at the Lab School. Were they able to deal with real-life situations as well as they had with the simulated academic tasks?

The students' collaboration was oriented toward completing academic tasks that were carefully filtered and crafted to keep students from being hassled with the troubles of the real world outside. With the simulated problems of pre-industrial society, the students were not addressing the problems directly drawn from their lives or from those with the potential to make a real impact on their daily lives outside school. The best Dewey and the teachers could do was moderate students' interactions within the school environment to help resolve the participatory issues and encourage their internal growth.

Dewey's (1916/1980), however, asserted that a school curriculum needs to bridge the gap between the school and the rest of students' life because we get to learn about the world only through active participation in the world. If students are encouraged to participate in a simulated problem, students only learn about a simulated world, not the real world. In addition, Dewey believed that schools should contribute to making real changes in students' lives outside school, not only through developing students' minds, but also through making changes in the community itself. In *School as a Social Center* (Dewey, 1902/1976b), he observed that schools could be a strategic center to make a better community. We need "to make the schoolhouse a center of full and adequate social service to bring it completely into the current of social life" (p. 80). Despite

his revolutionary vision, making real changes in society was not a primary goal for the Lab School. Dewey didn't know how to move beyond the concept of school as a contained learning center, and he wasn't able to encourage students to participate actively in community problems. Because of the discrepancy, Dewey often used the future tense when describing the school's role in helping students participate in community problems. He then "increasingly lost faith in the schooling system as the strategic agency to help democratize the American societal system" (Benson et al., 2007, p. 48).

Summary: Character-building education with simulated problems. Quite different from the students' interactions during the owl pellet activity at the Prairie Middle School, harmonious interactions characterized the curriculum planning and the operation of the lessons at Dewey's Lab School. Students at the Lab School had ample opportunities to interact with the materials or ideas and pursued their interests at their own pace. Because the textile industry project provided a rich environment for students' participation in various inquiries within the academic boundaries, I would mark the participation component high for the inquiry component triangle (see Figure 9). The mark wouldn't reach to the fullest, however, because of the set boundaries of the project and the lack of information on how students reflected on their inquiries.

Unfortunately, the collaborative participation didn't reach its full potential to make significant changes in students' important problems beyond school walls. Similar to the owl pellet activity, the textile industry project was selected by the teachers to simulate activities outside school rather than directly addressing students' individual or social problems. The students learned to collaborate to complete their academic tasks, but this particular task was somewhat isolated from their real life outside school. It's not clear how the learning outcome translated for their nonacademic tasks because the project was not aimed to effect changes directly to the outside world. Because the teachers at Dewey's Lab School allowed students to

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pursue their individual interests beyond the planned curriculum, I would give a slightly higher

value on both the relevance and the significance of their project than the owl pellet activity.

     While Dewey and the teachers at the Chicago Lab School boldly tried to change the

landscape of school education in the early 1900s, they were not able to embody Dewey's

revolutionary vision fully into practice, especially in terms of relevance and significance of the

projects. As an effort to better understand Dewey's 'school as a social center' idea, in the

following chapters I examine several contemporary education projects that encouraged students

to investigate their community problems to make real changes to their lives.
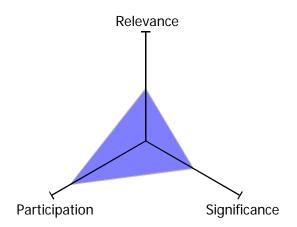

Figure 9. Inquiry component triangle for Dewey's Lab School.

Chapter 6

Whittier Elementary School

As an effort to show the relevance or application of science in students' everyday life, educators have tried to bring in "real-world" problems into the science class. Environmental topics are one of the most popular projects, such as testing water qualities of nearby ponds or rivers, and investigating a variety of organisms in local wetlands or woodlands. The Chicago River project at Whittier Elementary School (Bouillion & Gomez, 2000, 2001) could, on the surface, be understood as one such effort. The participating students had measured the water quality of nearby Chicago River and they also monitored the ecosystem around the river. The students investigated the water quality and the environmental issues in relation to the science curriculum.

This project, however, didn't start as a science teacher's effort to show the usefulness of science to the students. Instead, the students and the teachers *adopted* science in order to address a problem in their own community. They used the investigation as the groundwork for a series of community actions, and they mobilized the community resources to collect more scientific data. They shared what they'd found with the community through performances and discussions. Over several months they persisted in resolving the problem. When they finally succeeded in making a difference in the community, they were able to experience the power of a persistent scientific inquiry.

I examine the Chicago River project to understand distinct features and issues of implementing a community-based inquiry project in a contemporary school setting. The process of addressing a community problem provides an unusual perspective on how to link students' experiences with learning and make a significant contribution to their lives through a school project.

Contexts of Whittier Elementary School

Whittier Elementary School. The school is located a couple of miles southwest of downtown Chicago. The school serves over 500 students in grades K-6 in 22 classrooms (Chicago School Alliance, 2007). The neighborhood is composed of immigrant Mexicans and Mexican-Americans. Ninety-eight percent of student population comes from the low-income residents. The neighborhood faces the common inner-city issues of poverty, gangs, and speaking English as a second language. Because most of the students speak Spanish at home, the students are gradually introduced to English instruction. The lower-grade students are taught mostly in Spanish and the higher-grade students have 50 percent of their instruction in English.

The school declares its audience to be the community. The school tries to be a community school by involving the parents in the various school activities, working together with the community organizations to provide adult classes and services. The school had been involved in community environmental projects prior to the Chicago River project (Bouillion & Gomez, 2001). For example, the students, teachers, and parents had worked together to develop a couple of abandoned lots near the school into a community garden and a restoration prairie space. The participants of the Chicago River project previously had gone on a field trip to a forest just outside the city and had worked to help protect the land and the indigenous plants on site.

Project background. The Chicago River project was one of the school's efforts to connect learning with the students' experiences through solving their community problems. The teachers at Whittier Elementary were already discussing a collaborative project before they participated in the state-funded program called "Reality Based Learning". This project was designed to "explore the use of real-world problems and school-community partnerships as curricular anchors and contexts of learning for students" (Bouillion & Gomez, 2001, p. 881). The

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teachers wanted the project to offer not only positive impact on students' cognitive development, but also a reason to learn.

Many people participated in this project, including the teachers of two classes, the science teacher, the technology coordinator, the ESL teacher for those two classes, and a case researcher. A case researcher came in to the school to facilitate the project. As the project evolved, the parents, community organizers, scientists from Chicago Academy of Sciences, and community artists also participated in the project.

Analysis of the Chicago River Project

Research methods. For Whittier Elementary School, I referred to two articles, "Connecting School and Community Through Science Learning" and "Designing for Culturally and Linguistically Diverse Communities," by Bouillion and Gomez (2000, 2001). They describe the educational goals of the lesson, the progress of the project in connection with the participants' roles, and the impacts of the project on students' lives and the community. As a case researcher, Lisa Bouillion regularly participated in designing and implementing the project with the Whittier Elementary teachers. She attended the teacher meetings, observed the classes, interviewed the teachers and students, and collected students' work. I conducted multiple informal interviews with her on various topics for additional information. Although the interviews and two research reports supplied enough data to draw important educational implications for this study, I found that the analysis on the Chicago River project has the limitation of a secondary analysis and casts a rather idealistic picture of the project.

Chicago River project. The teachers at Whittier Elementary School wanted their students to investigate their own problem for this project. Instead of planning the topic ahead, they took the students on a community walk to observe the community. After the walk, the

students wrote in their journals about what they were proud of and what they'd like to see changed. With the teacher as facilitator, they discussed what they had noticed during the walk. They agreed that they were concerned about the riverbanks in the community that were covered with heaps of dirt and garbage (including milk cartons, dead car batteries, rat holes, and general garbage from illegal dumping). They wanted to see more green space in their community instead. After the class discussion, the students and the teachers concluded they would help clean up the rubbish and build a green space to play in with friends. Then they set up the main inquiry question in relation to the curriculum: What ecological systems are we in and how do we affect those systems?

After the inquiry question was recognized, the teachers met among themselves to devise activities to learn about the riverbank pollution and help resolve the situation. They also invited the students to contribute in evaluating what kinds of activities could be adopted for the project. They decided on a variety of activities, including "learning about pollution and ecosystems, developing a conservancy plan, collecting and analyzing data, sharing findings, implementing strategies for mobilizing community action, planning for riverbank restoration, and eventually working to secure lease rights to the riverbank land" (Bouillion & Gomez, 2001, p. 884).

These activities were not planned out at the beginning of the project. Instead they were dynamically constructed as the situation unfolded and new challenges emerged (see Figure 10). The students and teachers used a set of questions to plan and document their activities throughout the project. Before the students started each activity, they asked, "What do we think we know and what do we want to know." After an activity concluded, they asked again, "What did we learn and what do we still want to find out".

As the learning about the riverbank pollution progressed, the teachers and the students recruited outside partners who they knew would care about the riverbank pollution and help them

with the project (Bouillion & Gomez, 2001). The local scientists from the Chicago Academy of

Sciences and the Illinois Nature Conservancy helped the class with testing the water qualities and

other field activities. The Teachers Academy for Math and Science provided the curricular

resources. People from the neighborhood provided the local geographic information as well as

their perspectives on the project.

After collecting and analyzing the data of the riverbank pollution and ecology, the

teachers and students together planned the ways to restore the riverbank. They shared their

results with the parents and the community through a play and a web site. They formed a river

stewardship committee. They wrote letters to the city council to secure the leasing contract, and

Identification of Problem Polluted riverbank in community

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Learning about Pollution and Ecosystems (question-driven inquiry, river modeling, stewardship activities)	Developing Conservancy Plan (writing letters to landowner, collecting data, building community awareness)

↓ ↓

Original request to landowner to remove trash on riverbank was refused

↓ ↓

Collecting and Analyzing Data (water testing, trash survey to identify point source of pollution, community survey to identify conservancy awareness and practices)	Sharing Findings and Mobilizing Action (performed play on the environment to community, developed river webpage, made presentation at community hearings)

↓ ↓

Landowner brings in bulldozers to remove trash piles from riverbank

↓ ↓

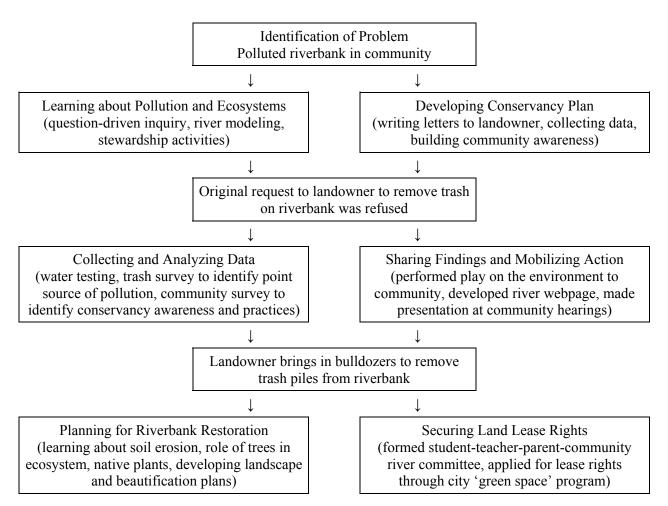| Planning for Riverbank Restoration (learning about soil erosion, role of trees in ecosystem, native plants, developing landscape and beautification plans)	Securing Land Lease Rights (formed student-teacher-parent-community river committee, applied for lease rights through city 'green space' program)

Figure 10. Evolution of the Chicago River project. (Bouillion & Gomez, 2001, p. 884).

to the landowner company to help clean up the garbage. When the landowner company declined their request, the students and teachers were disappointed at first, but they were determined to reach their goal. They discussed what more they could do. They collected more data and wrote more letters to the company. Due to their persistent requests, the company removed the garbage from the riverbank. After the community got the leasing rights through the city, the students and teachers developed a landscape plan of the riverbank with the help from local artists and started to beautify the area as a green space with flowers and plants.

Relevance. The Chicago River project was established by the teachers' efforts to empower their students to become active agents of social change. With the framework of *funds of knowledge* (Moll & Greenberg, 1990), the teachers believed the powerful elements of students' daily lives would be a strong motivator for learning. As a way of "bringing the powerful elements of day-to-day life that exist beyond school into school in powerful ways" (Bouillion & Gomez, 2001, p. 879), they tried to engage the students in a real problem within the community.

Features of a community-based project. Bouillion and Gomez (2001) detailed the features of the Chicago River project that worked as a productive community-based inquiry. First, the problem was based on the students' recognition of a community problem. There was a strong consensus among the students that it was their problem and they needed to conduct a collaborative inquiry to resolve the situation. Second, the locality of the problem made the inquiry situation highly visible and accessible for the students because the river was located in the community and the students could visit the site anytime they wanted to. When they passed by the riverbank site, they were able to check what was going on and see the impact of their inquiry. Third, the problem neither showed any clear solution at the outset nor involved any one's right answer. The teachers as well as the students were inquirers who sought to resolve the situation.

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In the process of developing their knowledge and seeking solutions, each member's imaginations and contributions were welcomed and the process induced more student participation. Because the inquiry was naturally interdisciplinary, each student was able to participate in the activity with his/her own expertise rather than being marginalized as useless. Lastly, the importance of the problem enabled the students to seek collaboration and to communicate with other community members, such as their parents, local scientists, and community organizers. In the process of informing them and trying to get their support, the students' understanding of and commitment to the project deepened.

Recognizing the powerful role of community problems for students' learning and identification (W. M. Roth, 2007), science teachers around the world have adopted similar projects for their students to learn the relevance of science to everyday life. In fact, the Chicago River project is hardly unique in terms of investigating community resources. Surveying nearby rivers/lakes and testing the water quality seem even more popular as a local problem due to their visibility and accessibility. Although the locality of the problem worked as a critical component for a productive inquiry for the students at Whittier, it doesn't automatically lead to the success of an inquiry project in other contexts.

For example, Jenkins (2002) cited a study conducted in Sweden, in which students participated in an environmental science study, quite similar to the Chicago River project in terms of science field tasks. Students researched two local lakes, which were affected by acid rain. After studying the lakes, they worked with public authorities and created a program to raise public awareness and remedy the condition of the lakes. Through the project, the students recognized the importance of what they were doing, devoted themselves to the project, devised ways to resolve the situation, and built their confidence in doing science and making changes in their environment. After hearing about its success, other schools copied the project. They

followed the protocol and let the students conduct the field tasks. However, it was not the same. These 'borrowed' projects were reduced to investigating some technical aspects of the water-quality testing of nearby lakes and adding lime. Naturally, the students were not able to see much value in the project and didn't show any strong commitment. Although the project started out to provide a valuable experience, it remained dull despite the locality of the problem.

The failure could be explained in relation to the students' experiences and the way the problem was contextualized. The project was not based on the students' recognition of a problem but adopted by the teacher to introduce students to some aspects of science, just like any other science lab. Although the topic might have been a prominent community problem, there was a weak consensus among the students in resolving the situation. In addition, the protocol and the outcome were already set when they started the project. It didn't require any planning or revising of the procedures, and consequently the students didn't need to contribute their experiences to the project planning or executing. Without strong consensus or dynamic elements in the project, the students felt they just did another compulsory task.[10]

Students' recognition as the starting point of an inquiry. The success of the Chicago River project seems to be due to the way the students constructed their inquiry question. The teachers didn't start out to test the quality of the water to teach the relevance of science. Rather, they deliberately elicited students' recognition of the community as the project's starting point. The environmental science activities grew out of a larger focus to figure out what was needed to remove the rubbish and how to build a community green space. The environmental study of the Chicago River was adopted as a means to achieve the goal, not the goal in itself. By letting the

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[10] I have to say that sharing curricular materials works as a great resource for teachers. Without many existing curricular units about water-quality testing and other topics, the teachers at Whittier Elementary might not have been able to guide the students through this project successfully. However, without the recognition of the limitations of the curriculum transfer, it may be harmful to borrow a curricular unit because it often destroys the dynamic nature of the curriculum construction.

students investigate a problem of importance in their community, the teachers increased the chances for students to voluntarily connect their experiences with the project, reflecting their surroundings and finding their own resolutions—an essential part of productive inquiry.

By not prescribing inquiry questions and procedures for students, the teachers took a risk. In addition to the unpredictability of emerging problems (Dewey, 1938/1991), generating a sensible scientific problem from students poses a challenge. It requires considerable scientific understanding and sustained engagement with a phenomenon, but those students involved in the Chicago River project were not generally recognized as fluent in scientific discourse (Fradd & Lee, 1999; Tobin et al., 1999). The teachers could have chosen to pursue the matter in a more teacher-directed way to make the students' project more scientific and better associated with the Standards or the existing curriculum (Bouillion & Gomez, 2001). However, it is noteworthy that the teachers wholeheartedly encouraged the students' own questions about the community *because* they, as ethnic minorities living in a low-income neighborhood, were often degraded by the society at large and were rarely included in scientific discourse (Bouillion & Gomez, 2001). The teachers were committed to community activism and keenly aware of the discrimination and marginalization of the neighborhood population. While many science teachers do not recognize civic education as their responsibility, building the agency of the students as well as academic achievement was the priority for the Whittier teachers. They wanted their students to get actively involved in community issues and make changes in their lives. They believed the students needed to experience a self-directed collaborative inquiry to identify themselves as effective learners/users of science and active agents of social change. The teachers said,

> [It's] for them to go out and feel like they're going to do something important for the world, you know… It's about doing something for their community, doing something that makes their community better.

It's about empowerment. It's about providing our kids with skills that will not only help them academically…[but it also] motivates our kids and gives them a reason to learn. (Teacher interviews re-quoted from Bouillion & Gomez, 2001 p. 883)

For those teachers, the potential benefits of the project—providing a motivating and empowering experience for the students—outweighed the risk of the dynamic construction of a project.

We can assume the teachers at Whittier were able to negotiate the educational goals as such, partly because they had human resources to draw the subject matter skillfully from students' questions. The 5th grade teachers worked with a science teacher, an ESL teacher, a technology coordinator, a librarian, and a university case researcher. Together, they believed that they would be able to guide the students' project into a more scientific, meaningful inquiry and draw elaborate links to the curriculum. Yet, it is necessary to note that at the beginning, the teachers were not 'experts' in every single aspect of the project (Bouillion & Gomez, 2001). There were topics the teachers hadn't explored before and they had to investigate those topics along with their students. Easley (1987) wrote that while teachers with a command of the subject areas are believed to be efficient in guiding students' activities, the anxiety to master the subject matter before teaching tends to lead a teacher to direct students into familiar procedures and stifle their creative thoughts. He argued, rather than obsessively focusing on the mastery of subject matters, teachers need to reflect the attitude of the learners who are willing to explore a topic with intelligence and enthusiasm. The teachers' strategy of being collaborators rather than authorities worked well for the project, as discussed in the next section.

Participation

Students' participation in many aspects of the project. The teachers at Whittier Elementary involved students in various decision-making processes throughout the Chicago River project, including setting up the topic, discussing the strategies to solve problems, linking the activities with the curriculum, and deciding the follow-up activities. The inclusion of students

in the decision-making processes was intentionally put in place to develop students' agency and was naturally called for because the inquiry question hadn't been previously answered for them. The interdisciplinary project afforded more room to utilize the students' individual differences, and the teachers made some adjustments to the project to create a way for every student to be involved and contribute to the project so that every student would consider themselves a valuable asset to the project. For example, for a writing project, the teachers created English-Spanish editor roles for the students who preferred English and those who preferred Spanish. It is not clear if all students participated in the activity with the same enthusiasm, or if there were any further attempts by the teachers to allow individualized inquiry projects like Dewey's Lab school, or if there were any nonparticipants like Alex from the Prairie Middle School. Inarguably, this mode of participation contrasts with the owl pellet activity in which the task didn't invite as much students' diverse expertise.

Involvement of community members and outside organizations. The community-based problem afforded opportunities for students to enlist parents, other community members, and outside organizations for the project. To involve their parents, the students conducted a community survey to represent their parents' ideas on the matter; they performed what they had learned in front of the parents; they invited the parents to participate in the after-school riverbank restoration activities and on the river stewardship committee; and they invited their parents to use their farming knowledge and teach them how to raise/sustain plants for the riverbank restoration. One student said,

> They [my family] were impressed. They said it was a good thing that I was doing this for the river. . . .[W]e were going to present what were our ideas to the community, and they soon started to listen to our ideas, and all of the people agreed with us to make better places for the community. (Student interview re-quoted from Bouillion & Gomez, 2001, p. 889)

Through engaging their parents in the project, the students were legitimately bringing in their home experiences, knowledge, and interests into school to share and extend, rather than dislocating them with academic discourses. Because the project was directly related to the life of the parents and community members, their input on community experiences and knowledge were essential components.

The teachers and students also recruited outside organizations that shared the same concern for restoring the riverbank, a green space, for the community. The Chicago Academy of Sciences, the Teachers Academy for Math and Science, and the Illinois Water Conservancy helped with water testing and other field activities. Park rangers at the Cap Sauer Forest Preserve taught nature stewardship to the students, and local artist groups helped the students develop landscape and beautification plans. The project also had a connection with the Reality Based Learning project that supports collaborative curriculum development effort with Illinois schools, universities, national laboratories, and the state board of education (Bouillion & Gomez, 2000).

Not only did the community and outside organizations help enrich the project with various activities and experts' guidance, their participation also broadened the perspectives on science by letting the students know there are a variety of people who practice science, and scientific expertise is distributed across many areas. Students often think of scientists in white lab coats with a strange apparatus in their hands. By meeting people who practice science in various places, students could envision themselves as scientific literates who would use science in their lives in various ways.

In addition, the participation helped the students to understand there were many scientists and other people who cared about what they were learning and doing for the community. The students were aware they were often looked down upon by the wider society because they were an ethnic minority living in an urban area. By communicating with people in a collaborative

manner, however, they gained a positive connection with many people, and confidence in what they were currently doing. They were able to view themselves as concerned members of society who would act for their community in collaboration with others.

Because the students recognized that many people participated in the project, they realized the project ultimately belonged to the community. They no longer thought of the cleaned-up riverbank as a future playground for their enjoyment only. They envisioned it as a place of learning about the environment for children, parents, and the community.

> I think I would build something or make it into a park, or a site where people [could] go to and think about the environment and do something about it.. . .I would get a lot of persons to go with me, like kids or students and teachers, to learn about it.

> I would build a place [for] people to go and have fun and [for] education, too. They would study about the…environment, what could help us and what hurts it… It would look like a little park and then a little house next to it—that's where people would go in and study about the environment. (Student interviews re-quoted from Bouillion & Gomez, 2001, p. 889)

The students now regarded themselves as part of the community and wanted to make the project serve the larger community members. Their broadened perspective on the project also seemed to say they wanted to share their learning experiences with other people so that they could participate in an act of conserving nature.

Involving multiple organizations in the project was crucial to the Chicago River project and beneficial for the students' learning. Despite such benefits, collaboration with outside organizations has not been often observed for learning science at school. I see three reasons that could make collaboration with outside organizations difficult: (a) whereas the Chicago River project was a real-world problem in which the outside organizations had their own interests, many school science projects are geared toward taking in already established scientific bodies of knowledge. Because this common practice does not require outside organizations' collaboration, teachers do not seek outside organizations' involvement; (b) while the Chicago River project

team was able to maintain the students' question at the center of the project throughout the collaborative relationship, collaborating with outside organizations often means that the outside experts take charge and steer the project to other objectives, leaving the students and teachers to follow their directions without knowing exactly why they were doing a series of experiments for a project.; and (c) involving outside organizations requires additional administrative work for the teacher's end. The Chicago River project had the human resources to share such administrative tasks, but many teachers do not have the human resources for managing additional collaborative relationships. Such difficulties for a collaborative relationship are not insurmountable but require reconsideration of how we approach learning at school.

Significance

Learning science. The student-led, community-based project of the Chicago River was successfully woven into the curriculum topics. For the science area, the students learned about water quality, soil erosion, soil quality, water conservation, and plant life. When they were asked about what they had learned from this project, they talked excitedly about the riverbank, how and why it was polluted, and how they contributed to create a green space. The students also showed their increased interest in science. In interviews, students talked in detail about various future study topics they would pursue in relation to the project.

> [I'd like to investigate more about] animals, like their habitat, what food they eat, what's [their] predators and prey; more about the animals. Nature…how do we take care of the trees…what do you need to do to help grow a lot of trees; agriculture. What kind of chemicals can you use to make the plants grow faster and better…I'm going to do that research in my own house; I would like to learn about the river or the woods and the environment and how they survive—the animals—and about if the river is being polluted more or less than last year. (Student interview from Bouillion & Gomez, 2001, p. 889)

They learned science in action, and their growing interest was a good evidence of learning.

Action-oriented science educators have observed that knowing something means having competency to engage in relevant actions (W.-M. Roth & Desautels, 2002). Roth and Desautels

argued that if students demonstrated the ability to successfully identify and address a scientific problem, it would be enough evidence of their learning of science (Aikenhead, 2002). Dewey would agree that the students of the Chicago River project demonstrated the confidence, resourcefulness, and persistence, along with their strategic experiment data and writing. They recognized a community problem and initiated an inquiry project; they recruited available resources to make the study trustworthy; they conducted multiple field tests to get necessary data; they gathered and used various facts and mechanisms to explain the test results; they wrote persuasive letters for the leasing company to remove the garbage from the site; and they also built self-confidence that their voices could be heard, and they were able to make a difference in the world through collaborative, systematic inquiry. They not only used scientific knowledge as the resource to solve important problems in their lives, but they also built identities as effective users and producers of scientific knowledge.

Although traditional ways of measurement would not be appropriate tools to evaluate students' learning from such extensive activities, science educators are often dissatisfied with action-oriented urban youth projects for not providing enough evidence of the science concepts the students actually learned. It is obvious that our views on knowing and scientific literacy guide our evaluation of students' learning. Yet, as much as understanding science is not limited to memorizing scientific concepts or circling right answers on school tests, contemporary science educators would lead us to think that participating in a scientific inquiry does not necessarily mean students have acquired elaborate scientific understanding. Rather than putting conceptual gains and participation as opposite ends of science learning—such as stressing participation and identification in scientific inquiry while overlooking students' conceptual understanding, or emphasizing conceptual understanding while ignoring students' participation—we would need to

elaborate on the meaning of understanding science in relation to participation or identification for better evaluation of students' learning.

Visible results. The Chicago River project is distinctive in its visible results for the students and the community. The project produced multiple scientific data sets, persuasive letters, and presentations. The garbage site was cleaned up, the ecosystem was partly restored, the community obtained the lease rights, and a committee was formed to beautify the area. The students recognized themselves as agents of social change, and the school-community partnership was strengthened (Bouillion & Gomez, 2001). One student shared the excitement.

> It made me really glad that grown-ups would listen to us kids because I thought they weren't going to listen to us because we're little kids. It made me feel glad when we went again to the Laflin River Site and we saw that the whole place was cleaned up. And now I think that I could do almost anything that I wanted to if I just set my mind to it. (Student interview re-quoted from Bouillion & Gomez, 2001, p. 889)

These amazing changes were, in a way, anticipated during the initial stage of the inquiry. When the problem was realized, the students and teachers framed it so that they would make an actual impact on the situation. This broad conceptualization of a situation beyond the school walls brought an immediate community change as well as an increase in students' learning of the river ecosystem and the nature of scientific inquiry.

This conceptualization of the situation and change illuminated how we could think of science learning activities. Traditionally, we tend to confine students' learning within school walls and try to simulate the outside world, like the activities at the Prairie Middle and Dewey's Lab School. This practice often fails to produce fruitful results for students' learning of the world as well as to create a change in the world. If we broaden our perspective of school activities to include community change as an educational goal, would we be able to achieve such remarkable results as the Chicago River project (Benson et al., 2007)? Before worrying about the lack of

school resources to mobilize the community, we would need to examine how making a community change could work for the benefits of students.

Summary: Visible results of the project. The Chicago River project can be characterized by its inclusive conceptualization of a problematic situation and its manifold impacts on the students and the community. Recognition of a real community problem shaped the inquiry to involve students' learning of science, collaboration, and agency as well as a community change. Science was adopted as a tool to resolve the problem, and collaboration was exercised as a resource. Participation was encouraged to address the situation from diverse angles, and, as a result, identification with scientific inquiry was established. Different from students at the Prairie Middle School or Dewey's Lab School, making changes around our lives was no longer irrelevant to the learning of science for the Whittier Elementary students. The community-based, problem-solving project thus would receive high marks for the inquiry component triangle (see Figure 11).

Although the project had a close link to a problem in the community, it is not clear how well the project was carried over for students' continuous efforts to inquire their own situations.
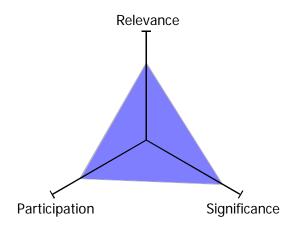
Relevance

Participation   Significance

Figure 11. Inquiry component triangle for Whittier Elementary School.

That is, what kinds of inquiry were the students engaged in after this project was over? Were they able to pursue another community-based inquiry project like this in class? Because of the lack of a mechanism to integrate students' concerns in school learning and bring in community resources after the big event, it is questionable how much the community-based inquiry was sustained in the school after the project. The next case, Pedro Albizu Campos Alternative High School, provides an alternative perspective to building a system to create a steady stream of further meaningful inquiries at school.

Chapter 7

Pedro Albizu Campos High School

As another community-based inquiry project, I chose an urban agriculture project at Pedro Albizu Campos Alternative High School. The project might look similar to the Chicago River project at Whittier Elementary School, but the project's position in the school operations does not. In Pedro Albizu Campos High, its community was systematically built into the school's operations and curricula. The urban agriculture project was a just part of a continuous effort to make a change in the students and the community. The strong emphasis on the school-community partnership shows another set of educational possibilities and limitations of community-based inquiry for providing a meaningful learning opportunity, especially for the underserved students in our society.

Contexts of Pedro Albizu Campos Alternative High School

Pedro Albizu Campos Alternative High School (PACHS) has a distinctive historical background, educational goals, and relationship with the community. The school's strong connection to its community is present in every aspect of the school, and its activities cannot be separated from the community actions and organizations.

Paseo Boricua and Pedro Albizu Campos Alternative High. PACHS is located in one of the neighborhoods in an immigrant Puerto Rican community near Humboldt Park in Chicago (three miles northwest of downtown Chicago). The neighborhood is often called the Paseo Boricua community. Paseo Boricua is the name of three monuments on the Puerto Rican flag. Each monument is made of 45 tons of steel and spreads along Division Street running through Humbolt Park. The monuments represent the Puerto Rican immigrants' historical and cultural experiences in the US, and declare the presence of a Puerto Rican community in the area. Many

Puerto Rican murals and shops are located around the monuments, and Puerto Rican cultural

activities are held year-round, such as Three Kings Day and Fiesta Boricua, which celebrates

Puerto Rican culture with food, art exhibits, music festivals, and children's entertainment. These

vibrant cultural activities are part of a broad array of community building efforts.

The Paseo Boricua community has traditionally suffered the consequences of poverty like

other stressed urban communities—gang violence, unemployment, school dropouts, drug abuse,

HIV/AIDS, unhealthy life styles, and dislocation due to urban gentrification (Flores-González,

Rodriguez, & Rodriguez-muniz, 2006). The people in the community, initially lead by Puerto

Rican independent activists, began to address their problems over 40 years ago with community

building efforts (Ramos-Zayas, 1998). Such activities included: making and distributing a

community newsletter; running a family learning center for ESL and GED programs; providing a

safe and affordable health care and daycare center; organizing HIV/AIDS awareness/prevention

programs; and arranging economic development programs in connection with the cultural

festivals (Bruce, 2007). One such community program was the founding of PACHS.

As the community realized that many of its youths were dropping out of school and

joining gangs, the community wanted to build a nurturing environment for the young, where they

would feel safe and motivated to learn (Antrop-Gonzalez, 2003). Combined with an incident in

the 70s, in which a few Puerto Rican students and teachers were expelled from a nearby high

school for organizing several strikes to demand a more culturally sensitive curriculum, the

community decided to have its own independent alternative high school (Ramos-Zayas, 1998).

The school was named after a prominent Puerto Rican nationalist, Pedro Albizu Campos.

Based on the Freire's educational philosophy, "education as liberation," the school

encourages the students to understand their own heritage, question common assumptions,

analyze social structures, and participate in community actions (Antrop-Gonzalez, 2003). In

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order to cultivate their cultural, historical, and linguistic resources, the school encourages the discussion of their cultural and historical identity. Not only do the students study the history, culture, and society from multiple perspectives in both English and Spanish, they also regularly discuss issues pertaining to their school and community so that they can participate together in an inquiry to address them.

The explicit commitment toward community actions can be noticed also in the location of the school. The school was originally housed in the basement of a church, but later moved to the Puerto Rican Cultural Center (Ramos-Zayas, 1998). The Cultural Center is the place where people come in to plan and organize community activities and it also has many books, articles, pictures, and artifacts about Puerto Rican history and culture. Because PACHS is housed in the Cultural Center, the students can easily access community resources and participate in community activities at the Center (Antrop-Gonzalez, 2003). Using the links through the Cultural Center, PACHS provides activities concerning a variety of topics, including health, legal, psychological, and financial issues.

While at college, the students continue to get involved in community projects. Some organize community actions against dislocation of the community due to the gentrification of the area (Flores-González et al., 2006). Many come back to the community after graduating from college to live and work in the community. The sense of "giving back" to the school and the community is strong among the students (Antrop-Gonzalez, 2003). One student's interview illustrates the students' sentiment.

> I came to [PACHS] with very little knowledge about my people, my community, and my history. But I came out with enough to give people a good argument, and to know what I am talking about. I chose to pursue my college education and major in criminal justice. I would like to come back someday and help my people, and of course my school. (Student interview re-quoted from Ramos-Zayas, 1998, p. 175)

PACHS is not only about building a critical perspective and participating in their community actions, however. It is also about providing productive learning experiences within a safe, caring environment (Antrop-Gonzalez, 2003). Most of the students at PACHS came to the school in order to escape gang activities or uncaring teachers (Ramos-Zayas, 1998). The principal of PACHS reported,

> Our students don't come here because they are consciously seeking a liberating education or because they support Puerto Rican independence. They come here because they know that this school will work hard not to neglect them and because they'll find out who they are. Hopefully, they will want to come back and continue their work in the community. (Principal interview re-quoted from Antrop-Gonzalez, 2003, p. 249)

While Chicago public schools have a large number of students, PACHS has only 80 students situated in a family-like school environment, like the traditional educational form of Puerto Rican culture. The student-teacher ratio is quite low (8 to 1), and there are school counselors and social services available at school. There is also a regular town hall-type meeting every other week so students can talk about and resolve their personal, social problems at school through a peer counseling process that builds a strong bond and agency in the students. The teachers have a very close relationship with the students, and they take the students bowling and dinner to talk about their problems and education (Antrop-Gonzalez, 2003). Because of such systematic support of the school and teachers' strong commitment to build a safe, caring place for the students, the students recognize the school as an extension of their family or sanctuary (Antrop-Gonzalez, 2003).

> [PACHS] is a family that cares and supports you and will always be there to give you advice when you need it. They care so much about our education. Teachers and students treat each other like a big family. We can feel safe coming to this school because no one will shoot or shank you because they assume you are gang related. (Student interview re-quoted from Ramos-Zayas, 1998, p. 172)

Due to the school's effort to provide cultural affirmation and a caring relation to students' lives, the dropout rate has dramatically decreased. Now, most students successfully graduate from high school and many of them go on to college.

Teachers. The majority of teachers and the principal at PACHS are very active community organizers, living within a couple of blocks from the school (Antrop-Gonzalez, 2003). They collaborate with other community members to plan and execute a variety of school activities and community actions, even during summer holidays (Bruce, 2007). They commit themselves to various community activities outside school, such as participating in protests, planning cultural events, or cleaning up the community. For the community's celebration of Fiesta Boricua during the Labor Day weekend, for example, the teachers worked with the students to hand out flyers, serve food, or clean out the streets until 2 a.m. (Antrop-Gonzalez, 2003).

In order to make the school a safe and productive learning place, the teachers take care of every aspect of the school. To assure students come to school, the teachers make wake-up calls, give them rides to school, or even literally drag them out of bed (Ramos-Zayas, 1998). In order to make that the school remains a gang-free, safe place, the teachers at PACHS keep their eyes and ears open to notice any gang activities and try various means to reduce its influences on the students (Antrop-Gonzalez, 2003). Because school funding and resources are limited, teachers have to devise creative ways to save money and utilize the existing resources. This effort includes having the teachers come in at 7 a. m. to prepare and serve breakfast for students, clean up the cafeteria after serving lunch, teach seven class periods per day, and stay at school as overnight security once a week (Antrop-Gonzalez, 2003).

Such an intense commitment to their students and the community occupies most of teachers' daily lives, leaving little room for their personal lives, and making it almost impossible

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to continue the job without very strong commitment to the students and the community. Most of the dedicated teachers accept lower salaries than their counterparts in the Chicago Public Schools, but with the enormous workloads and lower salaries, teachers from outside the community often leave the school after a few years, increasing the faculty turn-over rate (Antrop-Gonzalez, 2003).

Students. The students usually enter the school in their sophomore year. Although the tuition is not expensive compared to other private schools, the students generally receive a scholarship to fund their tuition. The student body consists of ethnic minorities, including Puerto Ricans from the neighborhood, some African-Americans, Mexican-Americans, and other Latinos. The students often come to PACHS after they have been expelled from or dropped out of a nearby public school. The school's accommodating environments invite many teenage moms to the school—about 20 out of 80 students are teenage moms who bring their kids to the daycare center at the school. Students are required to take traditional academic tests and assignments, and compile a portfolio of their work to show how they are participating in both school and community activities and what they learned from these experiences.

Integrated science class. The urban agriculture project occurred in the context of the Integrated Science class and Summer Institute. The Integrated Science class is designed for first-year students at the school (who are usually sophomores). The class progressed with a series of whole class activities because the class size was small (15 students). The curriculum involved the interdisciplinary nature of science, creation of the universe, and evolution. For the creation of the universe unit, students brought in their family's beliefs about creation, learned about scientific theories of the universe, and discussed the implications. Because there was relative flexibility in the curriculum, if the students introduced any interesting idea during class, the teacher would find related activities to explore further the idea the next day. The class didn't always do hands-on activities, however. There were lectures, discussions, and story telling. The teacher engaged

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in story telling to grab the students' drifting attention. These stories were often outrageous, and yet somehow woven into the science concepts about which the teacher was lecturing. The students took biweekly traditional paper-and-pencil tests on their study and turned in written assignments.

Analysis of Urban Agriculture Project

For the urban agriculture project, the students at PACHS worked mostly in the community garden. If we just looked at the students' working in a garden tending some vegetables, we wouldn't see anything special about this project. We have seen many gardening projects for biology classes—maybe because growing plants is a fun way to learn important concepts in plant biology and the value of hard work. However, this project at PACHS started out with a community-centered perspective and concluded with further inquiry questions for the students to work on.

Research methods. Because of its unique historical background and educational philosophy, a few educational researchers have documented the school's practice in detail. To understand the dynamic school-community relation of Pedro Albizu Campos Alternative High School, I drew from "This School Is My Sanctuary: The Pedro Albizu Campos Alternative High School" by Antrop-Gonzalez (2003) and "Nationalist Ideologies, Neighborhood-based Activism, and Educational Spaces in Puerto Rican Chicago" by Ramos-Zayas (Student interview re-quoted from 1998). Both Antrop-Gonzalez and Ramos-Zayas closely participated and observed the school activities over a long period and analyzed students' conceptions of the school. I also referred to several articles by B.C. Bruce (2007, 2008), "From Hull House to Paseo Boricua: The Theory of Practice of Community Inquiry" and "Coffee Cups, Frogs, and Lived Experience."

For this particular urban agriculture project at PACHS, I interviewed Michelle Torrise. She had worked as a graduate assistant for a year and helped to develop and evaluate the social ecology curriculum at PACHS. She observed the classrooms, helped the teachers, and documented the effort. Later, she worked with the students at a summer institute program at PACHS. She supplied thorough information on the development of the social ecology project as well as the students' participation. She also provided photos, school posters, web pages, and other documents relating the urban agriculture project.

Urban agriculture project. At the end of the 2006 spring semester, the students studied plant biology through a hydroponic garden. They cut two liter soda bottles, put them upside down, filled them with water and nutrients, and grew some plants in the classroom for their science project. The students were excited because they were able to see the roots in the clear bottles. They wanted to know how the nutrients and water worked to grow plants. It was a successful lesson, but the students forgot to clean the plants from the hydroponic garden unit. After a long summer vacation, the students found that the plants in the hydroponic garden were still alive as someone must have come in and put water in the hydroponic garden several times over the summer. They even had fruit on them.

Watching the thriving plants, the students got excited and wanted to keep going with the gardening in the fall semester. The teacher and students discussed ways to build a larger hydroponic unit, went out and bought an aquarium, pipes, and a pump, and made a hydroponic garden unit. As they tended the plants in the hydroponic unit they built, the students got excited. Everyday they came in and watched the plants grow. Some even came in after school or between classes to check on them. In class, they learned about hydroponic gardening in comparison to soil-based gardening—how plants grow without soil, the benefits and drawbacks of this method

of gardening, etc. They also talked about the possibility of planting more vegetables in community gardens and beautifying the community with flowers.

One day, the students sat down and discussed different issues in the community, such as gangs and domestic violence. As they talked about the gangs—what the problem was, what contributed to the problem, and what they could do to address the problem—they realized that people joined gangs because gangs provided some of their basic needs—food, housing, and some sense of safety. The students reasoned if they could contribute to providing those basic needs to the community, people wouldn't have to be involved in gangs as much. The science teacher then narrowed down the discussion to the food issue in the community. The students questioned whether it was a matter of not having access to affordable, healthy, and authentic food in the community. If so, how could they help address that issue? The student thought if people could grow their own food, they could supply their own food and wouldn't have to worry about how and where to get their food. They wanted to explore this possibility.

The students worked on their food-gardening inquiry with the science teacher during a summer institute. The main question was narrowed down to

> Residents of the Humboldt Park community have poor access to fresh, affordable, locally grown produce that is a part of the Puerto Rican cuisine. What steps can the community take to increase the availability of these foods at affordable prices to local residents? (Torrise, 2008, p. 2)

Everyday the students spent hours doing research in small groups. Each group established their goals, investigated how to implement their plans, and scrutinized what real impact they would have on the community. For example, a group of students proposed to build a rooftop garden on the school building to increase the vegetable supply. In order to decide which system they wanted to put in place, they examined the productivity of soil-based gardening versus hydroponic gardening for the vegetables they wanted to grow. Another group wanted to convert

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empty lots into community vegetable gardens. They investigated the environmental impacts of urban vegetable gardens. Another group wanted to have a greenhouse at the school for a year-round supply of fresh vegetables, and they examined how to secure funds to build it. Yet another group wanted to start a farmers' market to stimulate local vegetable growing. They studied the economic impacts of vegetable growing and the farmers' market for the community. They also looked into the possibility of bottling the vegetables for the market.

While they were doing their research, they rented two plots at the community garden and tested out their vegetable growing schemes. Their ultimate goal was to encourage people in the community to grow their own vegetables in their backyards. To investigate what was involved in growing vegetables in and around the community, the students grew certain vegetables. When they were ready to choose the vegetables to plant, they knew that their ethnic food, made with fresh local vegetables, would help build healthy diet habits. They grew the ingredients for sofrito, a Puerto Rican food base made with tomatoes, green chilies, cilantro, recao, and other vegetables.

(a) (b)

Figure 12. Gardens at Pedro Albizu Campos High School. (a) The classroom hydroponic garden, and (b) the community garden. These pictures were taken from the school photo gallery and then processed to hide the identity of the students.

As they were tending the garden, they were faced with various challenges and learned about farming techniques and skills. By end of the summer, they had sold some vegetables at a farmers' market at the park. They also made a Puerto Rican dish with the vegetables. They shared the food with the community at Batey Urbano, a community club where many social action projects were discussed and presented their research results. Many community members came out to the event and supported the students' projects.

Incorporating what the students had researched over the summer and what the community members shared at the meeting, the teachers at PACHS redesigned the curriculum focusing on urban agriculture in the context of social ecology. It was an interdisciplinary curricular theme to extend their inquiry. Many class activities and discussions were constructed based on the urban agriculture theme for the students to gain an environmental, economical, and sociological understanding of the community. The school also developed a health and food extension program with a nearby college for the students to deepen their knowledge.

Relevance

Understanding students' experiences. The students initiated this project after recognizing of some fundamental problems in the community—gangs, poverty, food security, and poor health conditions of its population, such as obesity, diabetes, and circulatory diseases. Their understanding of the problems was concrete and real because they had or knew someone who was affected by these problems. The issues, threatening the integrity of their daily lives, were significant parts of students' experiences, and the students motivated to do something about these problems to change their living conditions. The teacher was fortunately able to guide them to reflect and act on the problem through the project.

In the problem recognition process, the family-like school environment contributed greatly to the launch of the urban agriculture project. If the students at PACHS hadn't been able

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to openly discuss gangs and their living conditions with the science teacher, the project couldn't have started. Often science teachers focus exclusively on 'science matters' such as photosynthesis and chlorophyll. Nonacademic areas, such as life matters that include gangs and food security, are absent from class discussions. Science teachers often think their primary responsibility is to pass on scientific knowledge to their students. It is thought that dealing with students' nonacademic issues is something that needs to be passed on to the school counselors because of limited class time, the delicacy of students' life matters, or the uncertainty of success in such discussions. At PACHS, however, the science teacher was deeply involved in every side of students' lives, along with the school counselors and other subject teachers at the school. The teachers knew many students were struggling with serious life challenges, as they themselves had experienced as former students of the school or as community members. The teachers thus conceptualized teaching to include helping with a variety of the students' life challenges and actively encouraged them to talk about important matters in their lives—through school assemblies, individual counseling, and discussions in science class. Because of the teachers' all-fronts engagement and their deep understanding of students' life experiences, the students regarded their teachers as one of them, people whom they could confide in about important matters.

Recently some science educators have scrutinized their lack of understanding of the students' nonacademic experiences and cultures. Tobin (2002) wrote about how his unfamiliarity with the discourses and daily experiences of ethnic minority students in low-income urban area prevented him from successfully connecting with students and thus from positioning himself as an effective science teacher. However, looking at the PACHS case, the value of understanding students' social experiences is more than building rapport with students. It is the foundation to help students investigate significant problems of their own to make science learning meaningful.

The PACHS case shows that along with the school's open environments for sharing individual and social concerns, deep sympathetic understanding of the students' experiences helps them share their significant experiences with teachers for relevant, meaningful inquiry-based teaching. If understanding students' experiences—not just their misconceptions of science but their individual and social concerns—is a critical component of creating meaningful science learning environments, we need to re-conceptualize the boundary of science teaching to include the enjoyments and challenges in students' lives.

Students' initiation and teacher's planning. The teacher was able to guide the students efficiently with the problem, which at first didn't seem to relate to the science curriculum. The community and the teacher had been considering the issue and had carefully planned related activities prior to the students' discussion. Based on the students' interest and excitement in growing plants from hydroponic gardening, the community members met with the science teacher and decided it was time to do an urban agriculture and social ecology project, a project they had been thinking about doing for years. They were aware of the international urban agriculture movements to increase food security for low-income urban neighborhoods. They also knew that growing and supplying fresh vegetables in the community would help make the urban environments greener and better harmonized with nature. Furthermore, it would help improve the poor health conditions (obesity, diabetes, and heart disease) of the residents.[11] The community members and the teacher figured that doing an urban agriculture project would provide an opportunity for the students to participate in a community action and to understand their community better, in terms of their culture, healthy diet habits, and environmental issues. They

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[11] The statistics on the health conditions of Humboldt Park residents is startling. Thirty-five percent of adults and 62 percent of children are overweight or obese. The obesity-related problems, such as diabetes and heart disease, are twice as high as the national average. For example, 14 percent of adults of Humboldt Park have diabetes (Bickerdike Redevelopment Corporation, 2005).

extensively researched curricular units for an urban agriculture project in relation to social ecology. They also put in a proposal to buy the necessary gardening equipment and helped the students to investigate the issue further over the summer before school started in the fall.

Although the teacher knew the topic was relevant to the students' social experiences and the community development, he didn't hastily push it to them. Rather, he carefully staged the urban agricultural project. He first introduced a rudimentary hydroponic garden unit to bring out students' interest in gardening and urban ecology. As the students enjoyed the observation of plants and wanted to test hydroponic gardening versus soil-based gardening, he initiated a discussion of community issues with students. From the many issues plaguing the community, he narrowed it down to food insecurity and steered the discussion to what they could do about it. He demonstrated the link between the food security issue and students' interest in gardening. Then, he helped them inquire an urban agriculture project further, in relation to science, environment, and community development.

It was fascinating to observe how the teacher brought together the students' individual interests in gardening, the community's need for food security, and the school subject matter. Dewey (1902/1976a) knew that the curriculum needs to have a organic connection with the students' experiences, and teachers need to provide a rich environment for students to develop their individual interest in harmony with their social interest. Although the teacher was not consciously following Dewey, the teacher artfully brought forth students' interests and facilitated the engagement in a community-based inquiry project so that students could connect with the subject matter and the community.

Participation

Challenges in the process. Working at the community garden was generally productive. Many students enthusiastically participated in seeding, planting, watering, and tending the plants.

However, there were many challenges in growing the plants. For example, the students found that bugs and diseases were eating the plants. Different from the students' initial understanding, the plants required a lot of watering. There was no irrigation system in place, and a draught occurred, making it necessary for the students to haul buckets after buckets of water to the site. The plants they chose required not only water but a lot of sun. Because the weather in Chicago was quite different from Puerto Rico, the plant yield was not as abundant. In addition to the general issues of gardening, the students faced other challenges. Some fruit in the community garden was stolen one day, and some plants were vandalized on another day. The students were upset and discouraged. They were not able to understand why some people would do such things when they were trying to do something good for the community.

While those challenges baffled the students' efforts, they also generated a series of small inquiry projects and learning opportunities for them. They discussed how to diagnose and treat the diseases, the benefits and the dangers of using pesticides, how to manage the soil, and ways to increase yields. They learned about water shortage and changing draught patterns, and how they could help deal with other global environmental issues. They talked about how to productively manage collaboration and how to negotiate with other members of the community to find resolutions. This learning was not only for the students' benefit because the project was to become the groundwork for a larger community project. Community members would face the same problems if the students' campaign succeeded and the community started growing their own vegetables. The students' discussions and resolutions of the encountered problems could be used as a valuable knowledge resource for the community to draw upon, as the students were doing the initial explorative work for the community's gardening project.

When solving a real-world problem, we naturally face small and big challenges. The upside of having such challenging experiences at school was that the students had their friends,

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and they would work on the issues together. They also had the teacher, who would help them make intelligent decisions. Rather than meeting the challenges on their own, the students had opportunities to discuss and find resolutions more collaboratively and systematically. Overall, the inquiry didn't progress as smoothly as the participants had wanted, but it presented a valuable learning experience for both the students and the community to build the knowledge and skills necessary for collaborative community-based scientific inquiry.

Modes of participation by students. Because the students were able to relate to the project, overall they enthusiastically participated in the project. When they went out to the garden, they would get their hands dirty and observe the plants closely. When they found something growing, they got excited and continuously asked questions. They were curious about many things and had many discussions. Although the majority of the students participated in the project with enthusiasm, there were some students who were just not interested. To engage those students in the project, the teacher assigned them a variety of tasks for tending the garden, such as hauling water or pulling weeds. When they were inside, the teacher occasionally let them have some time off and gave them a break.

Observing the incomplete engagement of the students in the project, I wondered why some students didn't see the value of their work and commit themselves. The project was directly drawn from their community experiences, and they had initiated the project. Although I knew many students at PACHS were struggling with serious problems in their lives, such as domestic violence, teenage pregnancy, and gangs, I didn't understand why the students shut themselves off from this kind of inquiry projects. Maybe I was naïve to expect every single student would participate in this community-based inquiry project, like a feel-good movie. Maybe I needed to be realistic and accept that some students won't participate no matter what and be satisfied that the project did peak more students' interest than usual.

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I was reminded of Todd DeStigter's (2005) story in which students desired to learn about car repair, pregnancy, and immigration history rather than reading *The House on Mango Street* (Cisneros, 1991) and studying about their community (see page 64). Like those students, the unenthusiastic students at PACHS might have had different interests, or immediate personal concerns, that were not aligned with the urban agriculture project. They might have wanted to investigate something else, such as sex, friends, or family, in a personal way. Maybe they did not like working with the plants and food, or thought the project wouldn't really solve the community issues.

Although teachers at PACHS were good at communicating with students about their concerns, they tended to move all students along toward whole class activities—maybe because PACHS didn't have the resources that allowed individualized inquiries for those students whose focus was on more personal issues and not aligned with the whole class project, like Dewey's Lab School. In addition, because of the school's position in the community, the school inquiry projects were often geared toward community actions rather than addressing personal concerns. Such practice was able to draw many students' participation in a project but missed the opportunity to engage others in meaningful learning.

Collaboration beyond the school and the community. The school personnel and the students always regarded the immediate community as their primary partner, audience, and resource. This urban agriculture project was no exception. Not only did they start out the project based on a community problem, they also surveyed and worked with other community members to determine the needs and means of vegetable gardens. They used a community resource, the community garden, as their field site to experiment with gardening. They presented their research results in front of the community outside school, confirming that, for the students at PACHS, the community was the central and integral part of their curriculum.

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The PACHS students had worked within the immediate community without outside organizations' help. However, the collaboration with outside organizations brought in human and material resources to enable the school to plan and execute the urban agriculture project. For example, one of the university partners searched and examined the resources for the hydroponic garden unit in relation to the available materials and the state science learning standards. During the summer institute, an assistant from a research institute helped the students' research and put their findings together while they were doing multiple interdisciplinary projects. For the curriculum development after the summer program, a nearby college offered a course based on an advanced food and health study for the PACHS students. Like the Whittier Elementary School case, the collaboration with outside partners enriched the project in multiple ways.

Significance

Students' experience as the goal. Educators often understand that linking science learning to everyday life means using a few everyday materials to teach science concepts better—such as explaining the rust on nails as an example of oxidation or the bobbing rubber duck in relation to water density. Although it is important to use everyday materials to explain science concepts, such a strategy only focuses on showing a small part of the link between science and everyday experiences. It is doubtful that it would really help students to use science in solving their everyday problems and appreciate the full value of science. The urban agriculture project at PACHS, in contrast, aimed at a different kind of appreciation of science in students' daily experiences.

Like the schoolboys of Barbiana (1970), the students at PACHS started their project based on their recognition of a prominent life issue—the food insecurity in their community. The meaning making of their life experiences was the driving force of the project, and these experiences were closely examined to locate the primary source of the problem, repositioned to

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think of ways to improve them, then changed as the students acted upon those resolutions, and lastly reflected upon. Students' experiences were not just a device to teach science concepts. Rather, they were the goal of the students' inquiry. Science was a resource to help them understand a community challenge and make changes in their experiences in the process.

Because students would need scientific literacy to make sense of the world and live effectively in society, we need to provide opportunities for them to use science for their lives at school (Eisenhart et al., 1996; W. M. Roth, 2007). As the urban agriculture project and the Chicago River project demonstrated, a community-based, problem-solving project yields such possibilities with its organic connection to students' everyday experiences and with the alignment of individual and social interests (Burr, 2001; Cummings, 2000; Giles & Eyler, 1994; Kahne & Westheimer, 1996; Saltmarsh, 1996). Rather than focusing excessively on transmitting random science concepts or skills, we need to seriously consider community-based learning opportunities so that students experience the consequences of science learning on their lives.

Change on the situation. The urban agriculture project started out to afford the community more control over the production and distribution of healthy, nutritious, and inexpensive food. Although the students and the teacher worked hard on the project, the immediate effect on the community was not clearly visible like the Chicago River project. For example, at the beginning of the project, the students thought they could grow and sell 'tons of vegetables' to the immediate effect. Because they were inexperienced in farming and the community garden plots were small, they weren't able to achieve that goal. In fact, they sold the vegetables after harvest at a farmers' market and earned only $20! It was a humbling experience for the students. Farming was not an easy job, and their enthusiasm alone did not make fundamental changes for the community. Such difficulties and disappointments might be the

very reasons why most teachers do not engage students in tackling critical questions of community but direct them instead to a simulated problem of the outside world.

Although they didn't achieve many visible changes, the students did learn biology, farming, and collaboration as they were engaged in various problems. The teacher and students at PACHS are still working at the garden and researching more questions to address the issue. For example, the teacher continues developing and revising a curriculum for new students, integrating the urban agriculture theme in the context of social ecology. The students are also investigating the soil—its pH, nutrient compositions, earthworms as fertilizer, making compost, etc.—in order to increase the yield. For making and bottling a Puerto Rican sauce, students are learning the mechanisms of food processing and preservation. Their knowledge from those projects will be a valuable resource for the community.

Summary: Significant problem for community action. The urban agriculture project at PACHS cannot be understood separately from the school's involvement in various community actions because the school had been functioning as the social center of the community (Benson et al., 2007). The integration of the community's needs into school learning was systematically built in the school atmosphere. This urban agriculture project was also drawn from the community's needs and the students' experiences. Because it dealt with a significant problem in students' lives, and most of the students enthusiastically participated in the project, it would have a relatively high relevance score for the inquiry component triangle (see figure 13).

The project, however, didn't prove to be straightforward. The students faced a series of difficulties, and they had to devise ways to address them. The problem-solving process was challenging, but it turned out to be a learning opportunity for them to study plants, farming, and the environment more closely. It also drew collaboration with other community members and outside organizations. Although the project involved multiple activities to reflect emerging

questions, there were still some nonparticipating students—maybe because they were not able to investigate different questions or contribute to the class in a different way. If there had been a more delicate balance between individual and group projects in the class, they could have engaged in more meaningful learning and the participation component would have received a higher mark.

While the project was much anticipated, it didn't yield a visible change like the Chicago River project by the end of the year. This was not because the students and teachers didn't work hard on it, but the question had a different quality, and thus the transformation of the situation couldn't result in a similar form. Although the project didn't immediately improve the quality of life for the community members, the students' efforts contributed to the community's knowledge resources as a part of an ongoing continuous endeavor to build a better community and improve the life of community members. The students carried on their inquiry with refined questions, and the teachers developed more curricular resources from the project. I would give the significance component a high mark.
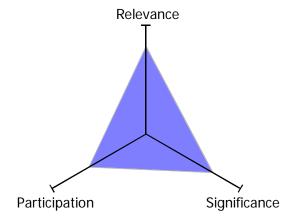
Figure 13. Inquiry component triangle for PACHS.

Chapter 8

Issues of Inquiry-Based Education

Inquiry-based education is often understood as an alternative teaching strategy from didactic lectures to solve students' motivational problems. Dewey, on the other hand, recognized that all kinds of learning could be characterized as inquiry. Even traditional didactic teaching could also be considered a limited way of inquiry because one may still learn something, but students don't have much chance to pursue and reflect on questions from their own experiences. Thus, the question we need to ask is not whether this teaching is didactic or inquiry-based, but is it the degree we want to encourage students' own inquiry learning.

This investigation shows many different layers of inquiry-based learning. The teachers in each case tried to adopt different approaches away from traditional teaching. Yet, some cases showed only minor differences from traditional instruction, and some others displayed more radical changes. Although none of the activities worked perfectly without any issues, each case was unique in its approach, problems, and solutions. The choice of a particular kind of inquiry teaching was tied to a set of values. Different versions of inquiry had different consequences. In this chapter, I explore which value each case focused on, in relation to the inquiry components that I drew from Dewey's theory of inquiry. I then conclude this study calling for a dialogue on which set of values we appreciate in teaching for scientific literacy.

Relevance: Understanding Students' Experiences

Primary learning goals and students' lived experiences. One of the distinctive characteristics of the inquiry-based education movement is its intentional link to students' everyday life. The National Science Education Standards assert that we need to teach science in connection with students' experiences in order to help them make better sense of science and

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understand its application in daily life. The teachers in all four schools aimed to connect the students' experiences with engaging hands-on science activities and tried to use them as valuable learning resources. Depending on the primary goal of the science teaching, however, there were distinct differences in understanding students' lived experiences and how they were utilized.

At the Prairie Middle School, the owl pellet activity was not conceptualized to address students' immediate personal or social concerns. The teacher's primary goal for the activity was to teach important science concepts and scientific inquiry skills, and possibly arouse academic curiosity. Understanding of the target science concepts could be beneficial to students' outside-school life in a long run, but the link was not particularly considered. Students' social identity development or community participation was not included in the curriculum. Because the teacher's prime concern was to help students acquire the target concepts and appreciate science, only the students' knowledge and interests in certain science topics were considered as relevant experiences for teaching. Their knowledge was explored at the beginning and again at the end of the unit to craft and evaluate the activity.

This conceptualization of students' experiences is widely accepted as those considered for science teaching. The students seemed to familiarize themselves with the materials to learn the concepts; however, I question that if the chosen concepts and skills didn't have any direct link to students' immediate concerns, how could students have realized the usefulness of science for their everyday life through the activity? If students' social and emotional experiences were not addressed, how could teachers have prepared them to become scientific literate citizens? Although those questions didn't seem relevant to students' science learning, my analysis showed that the lack of attention to these questions didn't help the students to make a genuine effort to the workings of the task and build important attitudes of scientific inquiry—personal

commitment (Matt and Steven's case), independence and confidence (Abby and Sharon's case), and collaborative considerations (Alex and Juan's case).

Similar to the Prairie Middle School, the teachers at Dewey's Lab School set a few important concepts and constructed activities accordingly (Tanner, 1997). The students' experience was translated to what they knew and to what degree they were interested in academic topics. Students' understanding of the topic was the main concern for the teachers, and they monitored students' cognitive development through the process.

Different from the teacher at the Prairie Middle School, however, Dewey and the teachers focused on students' character development as well as academic development. Students' relationships with other school members and with school environments were seriously considered. When students were not well aligned with school activities or had any trouble, the school provided room for the students to pursue their personal interests and to develop collaborative relationships with other school members. Dewey's Lab School broadened the consideration of students' experiences to include moral aspects and also encouraged students' independence and social development. Students' identity and social relations within school were closely monitored and moderated. This approach might have invoked more participation from the students at the Prairie Middle School.

The social experiences for teaching were limited to those within the school walls. There was little chance for students to explore their social relations within the larger community. Because Dewey (1916/1980) believed schools should remove undemocratic features of the outside world, students learned how they should interact in the outside world through collaboratively simulating various social activities at school rather than bringing in and participating in real problems from the outside world.

For the Chicago River project, the teachers set quite different learning goals than their regular science activities. The teachers hoped the project would help students realize their power to bring about social change and get engaged in scientific investigation. They considered not only the students' academic development, but also their identity development as a low-income, ethnic minority in the society (Bouillion & Gomez, 2001). Because the primary educational goal was set as such, different parts of the students' experiences were brought in for the project, thus acknowledging it as their local community's problem. Instead of assessing students' conceptual understanding of a scientific topic, the teachers began the project by surveying what students recognized as community problems and what they could do about them as a group. After they identified the problems, the teachers evaluated students' knowledge and skills in relation to the tasks so they could relate the topic with academic activities.

By extending the students' lived experiences to include a community problem, the teachers led the students to experience unusual school activities that dealt with the problem and valued their family resources. Although the project was drawn from students' shared recognition of a community problem, it is not clear how foremost the problem was in students' life in the first place and how much they reflected on the project in relation to their everyday life. In addition, it is questionable how the experience from this project was carried to other school activities, considering that it was a special collaborative project with universities and other organizations, away from their regular class activities.

The urban agriculture project at Pedro Albizu Campos High School seems very similar to the Chicago River project in two respects: (a) the projects were based on students' recognition of their community's problems, (b) and teachers tried to develop students' agency of change. In spite of the similarity, the urban agriculture project deviates on one important aspect—the established mechanism of bringing in community issues into school learning. Community issues

were brought in during student assembly, home visits, counseling, and class hours. The teachers at this school saw the community to be its curriculum and tried to immerse students in community actions (Bruce, 2007). Because of the school's extraordinary environment that brought in students' community experiences for school learning, the students' recognition of gang issues was artfully paired with their growing interest in gardening for the urban agriculture project. Based on his understanding of students' interest and community's needs, the teacher was able to plan and guide the project as a students-initiated, community-based project.

The teacher was successful in nudging students to investigate a community problem as a whole group, but individual students' immediate concerns might have been different from the community problem the class was addressing. How much was the teacher able to guide students in investigating their individual concerns or interests while the teacher was committed to community activism and the class was involved in such a community action project? It is also questionable how much students' emotional, physical, and social experiences were incorporated into school science activities.

Questions on learning goals of school science. All teachers in the four selected schools utilize some form of students' lived experiences to provide productive learning experiences. The differences in understanding of students' experiences bring forth a few questions regarding educational goals in school science. First, what kinds of students' experiences do we need to consider as relevant for the teaching of science and how far we do want to go with them? If we consider students' experiences as a whole and draw school activities from them, how can we make sure the activities connect well with science and that students are able to deal with them? If students' experiences require addressing issues of independence and collaboration, would it be wise to have such activities in class, especially in this era of achievement tests? Second, do our schools need to address community problems, such as treating them as community centers? Isn't

teaching students science enough responsibility already? How can we do other things while we are trying to keep up with our responsibility? At the present time, we remain without such mechanisms or resources for community participation projects. These questions need to be understood in terms of (a) how we position the value of ordinary experiences in the learning of science; (b) what we want to teach as science in school; and (c) the role of schools as social institutes for education. In the following, I elaborate on the issues with Dewey's theory of inquiry.

Ordinary experiences and teaching of science

Continuity of experiences. Dewey saw a tremendous educational potential in the ordinary experiences of our lives. He defined inquiry as our sense making of the world and argued that ordinary experiences pose great opportunities to understand the world in our own terms as well as improve our lives. The vision of scientific literacy likewise highly values our experiences, in which we are to recognize an important problem in our lives, conduct a systematic investigation using science, and make changes in the environment. Thus, for both Dewey and scientific literacy, our everyday concerns are understood as the start and the end point of scientific inquiry *in our life*.

In contrast to this understanding, students' life matters generally do not hold such a prominent position *inside* school. We say, students will reflect on and improve their lives when they have enough scientific knowledge and attitudes. It's just inefficient to guide students to deal with their life matters scientifically while they're still learning at school. Furthermore, we say we'd better prepare students to conduct scientific inquiries in the future rather than let them struggle with the weight of real problems while at school. When students have accumulated enough scientific knowledge, we argue, they'll be able to piece together various components of scientific inquiry to deal successfully with their problems.

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Dewey agreed that we need to prepare students for future inquiries, but he focused on the continuum of present and future experiences. He argued that preparation for the future needs to be understood as engaging students in learning activities resembling the desired future experiences. That is, if we want our students to engage scientifically in their future life matters, we should help them fully engage in addressing their present, real concerns as their real preparation for future.

Like in the Chicago River project and the urban agriculture project, when students were engaged in solving the problems in their lives together as a school activity, they could realize how science actually matters beyond school walls and understand science as instrumental knowledge to help solve their life's problems. Then, it is more likely they would continue doing the same thing outside school—using science to solve important things in their lives—as active users and producers of scientific knowledge, not merely as a passive knowledge reservoir. On the other hand, when a school activity is separated from students' real concerns, like the owl pellet activity, it increases the possibility of having students minimally participate in a science activity or engage themselves in a different kind of inquiry of their own. As they didn't experience how to use science to address their real concerns in class, they may not know how to use science for answering their life questions or the instrumentality of science. Then, how likely will it be for them to be able to conduct scientific inquiry outside school? Dewey wrote,

> In critical moments we all realize that the only discipline that stands by us, the only training that becomes intuition, is that got through life itself. That we learn from experience, and from books or the saying of others, only as they are related to experience, are not mere phrases. But the school has been so set apart, so isolated from the ordinary conditions and motives of life, that the place where children are sent for discipline is the one place in the world where it is most difficult to get experience.(Dewey, 1900/1976, p. 12)

Based on his understanding of the present-future continuum, Dewey defined students' everyday experiences as the ultimate goal and outcome of learning. He critiqued the underutilization of

students' experiences for learning at school as the lack of understanding about the real value of experiences for education (Dewey, 1938/1988).

Continuum of experiences and the curriculum. When we try to allow students to investigate their own experiences at school, however, we wonder how we could actually teach the required body of knowledge. We don't want to impose the established body of scientific knowledge on students' ideas and snuff out their initiatives, but we know they need to learn it in order to make their inquiry scientific. Furthermore, we have a list of important scientific knowledge to teach and it may be hard to link it with students' experiences.

Dewey offered the reason for this dilemma as the rigid differentiation of subject matter knowledge versus students' experiences (Dewey, 1902/1976a, 1938/1988). He understood that science as a school subject matter is not a fixed, ready-made entity in itself but is flexible enough to be organized in different ways for various pedagogical purposes to allow multiple access points for individual students. Learners' experiences are also flexible enough to expand and appropriate new experiences if they see their relevance or usefulness. It is the educator's responsibility to find the subject matter within students' experiences and artfully draw the link to the learning of science in order to open up the educative possibilities of students' experiences for better learning of science.

Contrary to the common perception of experience-based teaching, establishing such a seamless connection between students' experience and school learning requires much more effort and expertise on the teachers' part. We need to find the link and help students access the domain of scientific knowledge while investigating their own experiences. Teachers would need not only a thorough understanding of the subject matter, but also a good understanding of students' experiences, ways to shape them into more educative ones and to creatively utilize the

environment, for students to realize these links to the body of scientific knowledge. Dewey wrote

about the extended responsibility of educators who want to facilitate inquiry-based education.

> A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth. Above all, they should know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worth while.

> Traditional education did not have to face this problem; it could systematically dodge this responsibility…There was no demand that the teacher should become intimately acquainted with the conditions of the local community, physical, historical, economic, occupational, etc., in order to utilize them as educational resources. A system of education based upon the necessary connection of education with experience must, on the contrary, if faithful to its principle, take these things constantly into account. This tax upon the educator is another reason why progressive education is more difficult to carry on than was ever the traditional system. (Dewey, 1938/1988, pp. 22-23)

Because of this added responsibility, Dewey warned, it would be more difficult for teachers to

implement inquiry-based education. Our current school structure does not seem to provide

enough support for teachers to customize their teaching to students' experiences.

Our commitment toward experience-based learning. In the face of such a challenge, we

need to ask if we fully appreciate the prominent position of students' ordinary experiences in the

learning of science to make such efforts. How much do we believe in the educational possibility

of investigating students' own experiences for the learning of science? How much do we value

the continuum of the present experiences for building desirable future experiences? Are we truly

committed to experience-based learning, enough to make such radical changes in our teaching?

Without clear answers to such questions, our efforts to build learning activities from students'

real experience will dwindle over time.

Science within an interdisciplinary project. Community-based, problem-solving projects

like the Chicago River project and the urban agriculture project seem to be "de-centering

science" (Bouillion & Gomez, 2001, p. 893). The students in those projects didn't spend the

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whole class time discussing water quality, the environment, and plants in scientific terms. They spent a large portion of their time on nonscientific tasks, such as writing letters, persuading their neighbors to join their cause, and discussing their frustration about vandalism. These activities don't look like they involve much science.

Science teachers could dismissively say such integration projects are not for their students. They don't have time to fool around. They need to help students get familiar with science topics and gain conceptual understanding so that they can successfully take the standardized achievement tests. They are not going to be evaluated for how well they are able to write letters or how well they could express their frustrations. Moreover, such integration projects with everyday life is inferior to pure academic science teaching and only suitable for nonacademic track students (Jenkins, 2002). Such recognition of an integrative science project in our society could have contributed to making many school activities oriented toward academic tasks, whereas the PACHS and Whittier students were pursuing an integrative project.

By actively engaging in those seemingly nonscience-related activities, however, the students at Whittier and PACHS were building the skills to conduct scientific inquiries as a whole. Writing reports, persuading stakeholders, and managing unexpected results—these are observable and integral features in any reflective human inquiry and often lead to exciting new discoveries as seen in many historical events in science. In this sense, the students participating in integrated science projects were not abandoning the learning of science. Rather, they were growing out of the traditional sense of school science and were broadening their perspective on science to include various components of a reflective human inquiry. They were practicing scientific inquiry in a fuller scale to learn that it is an effective tool to address their problems in life.

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Thus, the critique of de-centering science when doing an integrated inquiry project needs to be understood in terms of what we include as science. Do we see that science consists mostly of discussion for conceptual clarification and building lab skills, like distinguishing a femur from a humerus, or do we see science as an integrated human act involving many components, such as dealing with unexpected outcomes or uncooperative stakeholders? We need to define what we want to teach as science and what we evaluate as science, rather than dismissing the integration projects as nonacademic.

Teaching science and values. Novice science teachers often think they are ready to teach if they know the science material (Jenkins, 2002; Tobin, 2002). They may admit students' learning is not a simple process and they need to understand students' experiences to diagnose the development of their knowledge and skills. Still, within this framework, the teachers' job is understood primarily as delivering science content knowledge, not as teaching for positive construction of identity and social relations. Science teachers often feel awkward in talking about values because science is recognized as objective and uncontroversial, whereas English or social studies invite discussions on values and experiences. If science teachers ever talk about values, it is often about the general socio-ethical issues of science, not about students' own experiences because it's not science teachers' job to engage students in critically and reflectively thinking about their personal lives. It is the school counselor's or other teachers' job.

Many insightful teachers, however, would disagree. In reality, teaching science content is only a part of the job. Students establish their identities and values while interacting at school, and their social and academic experiences influence what they learn and how they learn it. As the analysis of owl pellet activity shows, and as many researchers have argued (Barton & Osborne, 2001b; Dewey, 1896/1972a, 1902/1976a, 1938/1988; Eckert, 1989; Eisenhart et al., 1996; Gallas, 1997; Pintrich et al., 1993; Tobin, 2002), teaching and learning cannot be separated from who we

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are, what experiences we have, and how we relate to others. Just expecting that students will eventually learn democratic values, preferably at home, is irresponsible, not because there are so many dysfunctional homes in our society, but because our values and relations are embedded in our teaching practices at school. When a teacher understands students' experiences as a whole and encourages them to develop themselves socially, emotionally, and academically, they excel, as many of my undergraduate students remember their most memorable learning experiences. In addition, in order to teach students to become scientifically literate citizens of society, we also need to guide them to develop the attitudes of active and reflective learners through school activities (W.-M. Roth & Desautels, 2002).

In spite of the importance of the integration of value education as related to science education, our school system overemphasizes academic development in a limited sense. The school accountability system, for example, holds the school responsible for its students' academic performances based on the standardized test scores. School reports don't show how collaboratively students work at school, how reflectively they apply their knowledge to their life matters, or how self-directly they involve themselves in productive inquiry. As long as students score high on tests, the school is regarded doing a good job.

In my opinion, schools, along with parents and society, should aim to make safe and productive environments for the fullest growth of the young (Dewey, 1900/1976, 1916/1980, 1938/1988). Not only do teachers need to understand students' social, experiential resources for productive learning of subject matter, they also need to help them build reflective attitudes through school interactions for richer lives outside school. However, our schools have been exclusively focusing on academic achievement as the top priority. Rather than blaming students for not exercising democratic value sets, we need to examine carefully what we mean by growth

in our school education and how we are encouraging it if we want to help students achieve their fullest potential.

Community school. Bringing in community problems as a students' inquiry project was influenced by the school's relation with the community. PACHS had had a strong link to community action for years. The students and teachers were involved in various community projects in addition to the urban agriculture project. Because they had a commitment to make the school a social center, they made it their top priority to address the needs of the community. On the other hand, the Prairie Middle School didn't have any such relation to the community. It received funding and resources from the local community like other public schools, but the school wasn't involved in any serious community-based, problem-solving projects. As an institute to educate children, the school was positioned to focus on students' academic achievement, not on their engagement in a community problem-solving process.

From the case analysis of PACHS and Whittier Elementary School, however, the high level of community participation didn't seem to compromise the school's role as an educational institute for children. Rather, it seemed to help develop students' minds toward scientific literacy. The community problems worked as a shared interest among students, and they had a chance to experience an actual problem-solving process. The experience helped them to use science to realize the usefulness of thinking and talking science for important problems in their lives outside school walls. It also helped them build deeper scientific knowledge and appreciate the outcome of their effort (other than their grades on report cards). On the other hand, according to Benson, Harkavy, and Pucket (2007), when we understand schools as a contained learning center and limit teaching and learning within school walls like the Prairie Middle School or Dewey's Lab School, students' outside-school experiences became a secondary or invisible component. Students' knowledge is constructed without relevance, significance, or lasting meaning to

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students' life away from school. If any connection to their lives occurs, it is accidental rather than sustained.

Benson and his colleagues (2007) further asserted that school education needn't and shouldn't stay that way. As the growing number of service-learning or community-based learning projects has shown, local public schools could work as a social center for diverse community members to bring in and address their problems together. With systematic collaboration with outside organizations, students and teachers could contribute to building dynamic, field-based knowledge of the real world and transform the community into a better place to live. Granted, schools can neither fix every problem of the community, nor can every school activity be planned as a community-based, problem-solving project. Yet, we need to consider such strategic, new roles for schools to realize meaningful learning and a more democratic society. Dewey would agree with these points, considering he observed the world exists in dynamic relation with our experiences, and in order to understand the world, we need to purposefully engage in the world around us.

The question of adopting a community experience for students' learning then becomes not just about how we're going to prepare for *a* community participation project under the current school setting. Rather, it becomes how much we appreciate Dewey's view on pragmatic, participatory knowledge over traditional sense of contemplated, remote knowledge, and if we are ready to commit ourselves to reposition our schools as social centers to help communities to learn and transform the environment into something better than what we have now.

Participation: Understanding Inquiry Process

Flexibility in construction of learning projects. Although all the teachers in this analysis tried to build a collaborative, democratic relationship with their students, there were

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clear differences in the ways of drawing students' contributions into organizing the school activities. For the owl pellet activity at the Prairie Middle School, the teacher carefully mapped out the procedures at the beginning: what students were going to learn; how they were supposed to proceed with the task; and how they were going to be graded. It was well organized to guide pupils through, but left little room for students to reconstruct it dynamically. The teacher remained as the director, designer, and evaluator of the activity. The students thought the project belonged to the teacher and in order to succeed in the project, they needed to "pay attention to the teacher; do the work and turn it in; make sure it's right; and don't play around in class." While the teacher believed he was helping students become independent, collaborative learners, their chances to exercise those values in class were limited.

Although the teachers at Dewey's Lab School introduced the textile occupation project, the students were valuable contributors in planning and evaluating activities. The teachers didn't provide a firm outline of the activities at the outset of the project. Instead, they loosely arranged the project to accommodate students' dynamic construction of activities. The students discussed the challenges or possibilities of activities with the teachers and made changes together. Even when some students had trouble following the interests of the majority of students, they were guided to pursue their own interests with a different set of activities. The dynamic construction of the activities and the collaborative relationship with the teachers led the students to feel ownership over the project and employ collaborative attitudes at school.

The Chicago River project at the Whittier Elementary School went one step farther. The teachers didn't set the task in advance but let the students identify the problem. The teachers then discussed with them what activities would help to address the problem and how they could be linked to learning the subject matter. The emergent nature of the project kept those plans tentative in nature, demanding reflections, revisions, and contributions from other teachers and

outside organizations. The urban agriculture project of PACHS was similar to the Chicago River project in that the activities were dynamically organized through negotiation with the students and through considerable contributions by community members and outside organizations.

Questions on different contributions by students. The different approaches of curriculum development invoke a series of questions of why some activities were organically developed, and what made the students significant contributors rather than passive followers of the curriculum. Were some groups of students better prepared to participate in curriculum planning than others? Were there any particular contextual components that enabled the flexible curriculum planning? As a result of such construction of the curriculum, what did the students learn as the meaning of participating in a scientific inquiry project?

Readiness of students. We often believe that flexible, inquiry-based curriculum planning is appropriate only for high-achieving, model students. However, the students' maturity or level of scientific knowledge doesn't explain the difference in flexible curriculum construction because the 5th grade students at Whittier Elementary School wouldn't be regarded as more mature or knowledgeable in planning and executing school activities than the 8th graders at the Prairie Middle School. Nor did any particular issue pertaining to ethnic or financial backgrounds prevent students from planning and executing the school activities. Low-income Latino students at Whittier Elementary and PACHS as well as the affluent European-American students at Dewey's Lab School were able to contribute to the curriculum construction, much more than students of the Prairie Middle School with diverse backgrounds. What then are other major qualities in students that led the difference in the curriculum's flexibility? Or have we overemphasized the students' background as the reason for not allowing dynamic construction of a curriculum?

Participating in curriculum planning is a way for students to take ownership of their learning and establish themselves as active participants in school activities. However, low-income minority students are often deprived of such opportunities because many educators perceive they are distant from scientific discourse or hard to work with (Tobin et al., 1999). Even with the same resources, teachers in low-income urban schools adopt more highly structured, drill-oriented instructions than their counterparts in affluent neighborhood schools, blaming the students' low ability (Michaels, Cazden, & Bruce, 1985). With their schools' insistence on obedience, students in inner-city schools think that speaking up in class is bad because it means poor discipline and rude behavior (Fine, 1991). This perception and practice don't leave much room for students to voice their ideas in curriculum planning and learn science in relation to their experiences (Barton & Osborne, 2001a).

As Delpit (1988) cautioned, merely inviting students' participation may not be enough to overcome educational inequity. There are many difficulties in embodying the voices of the marginalized students into the curriculum (Ellsworth, 1989). But as seen in the Chicago River project and the urban agriculture project, when given a chance, the historically underrepresented students could rise to contribute to an experientially relevant curriculum for better learning and for a more democratic, equitable practice of curriculum planning.

Desired learning outcomes and students' contributions. Involving students in curriculum planning was not only linked to building democratic learning environments, but was also linked to the desired learning outcome of the activities. Depending on our primary means to get students acquainted with scientific inquiry, we seem to be choosing how much we allow students to contribute to the curriculum construction. While Mr. Keith at the Prairie Middle School believed science is about creative ideas, he wanted his students to follow certain steps and acquire the established scientific knowledge and skills regarding owl pellets. Because a

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deviation from the anticipated activity would not lead to the targeted learning outcomes, the teacher wasn't able to encourage students' dynamic reconstruction of the activity, and it led the students to become more dependent on scientific authority. On the other hand, the teachers at PACHS and Whittier Elementary School wanted to teach their students the process of a scientific inquiry by identifying their problems and shaping the procedures themselves. Because the teachers didn't know for certain what the inquiry would entail and how it would turn out at the outset of the project, students might have felt frustrated when faced with the challenges in the process, but they were able to contribute their ideas to the project design and examine how it worked out to address the problem.

Dewey (1938/1991) observed that the inquiry process is a process that inquirers construct dynamically in order to address a problematic situation—analyzing a problematic situation carefully, shaping the goals and procedures, and reflecting on the results. It means teachers facilitate students to get a first-hand experience in scientific inquiry process by engaging them in the process of design and evaluation of science activity in class. Through the vision of scientific literacy, science educators appreciate science not only as an established body of knowledge and skills, but also as a pragmatic tool to solve important problems of our lives. They argue we need to help students build knowledge and confidence so that they can initiate and conduct a scientific inquiry to enlighten and reorganize their experiences. However, without understanding the different focus of immediate learning outcomes for scientific literacy, we find ourselves blaming individual teachers for not being flexible enough, or the activity for not being systematically planned, or students for not learning a substantial knowledge about the scientific inquiry process. Instead of blaming, we need to examine what we mean by the scientific inquiry process, which values we want to instill in students, and how we should equip them to conduct a systematic, reflective inquiry, inside and outside school. Only then, can we evaluate how well we are

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embodying that ideal to better educate our students to perform scientific inquiries in accordance of the vision of scientific literacy.

Collaboration with teachers and outside organizations. From the difference in the ways of constructing curricula, we need to recognize the variation in utilizing community resources. Because the owl pellet project was already set and no major changes needed to be made in the process, the class didn't need outside help to make the project successful. On the other hand, the teachers at Whittier Elementary School, PACHS, and Dewey's Lab School sought outside help to construct the curriculum dynamically, not only because the teachers wanted to expand the learning resources beyond school but because the projects demanded collaboration with outside partners to supply all the necessary resources. They needed to enlist curriculum resources experts to create related learning activities; science experts to provide up-to-date scientific measurement tools; community activists to propagate their agenda; city council members to explain how legal procedures would work to attain their goals; and university resources to help organize the collaborative project. Those resources poured the necessary materials and the collaborative energy into the project. Without those outside resources, the dynamic construction of inquiry would have been impossible.

Such an enormous amount of collaborative effort for the projects, however, is not often dreamed of at school without some outside initiatives. The current school structure is isolated from outside organizations, and it doesn't have an efficient, sustained network to support students' learning beyond the school walls (Benson et al., 2007). If a teacher decides to construct a curriculum dynamically, s/he is on his or her own to negotiate with students and recruit outside partners. The problem then becomes not only whether we would like to support a dynamic curriculum construction with students, but also how much we are willing to build a link to

outside resources, on top of our already overloaded schedule, in order to expand students'

learning experiences and construct students' inquiry collaboratively and authentically.

Significance: Transformative Learning Experiences

The learning outcomes of a science activity are often defined as individual students'

development in science concepts and skills, such as the understanding of ecological balance or

performing water quality measurements. An increased interest in science and confidence in

conducting scientific inquiry could be added to the outcomes of inquiry-based activities. The

internalized knowledge and values are most commonly referred to as learning outcomes, and so

far I have explored how those learning outcomes were pursued and achieved in each of the four-

presented cases. However, Dewey also stressed the external outcomes of learning, or more

accurately, the transformative side of genuine learning experiences. Rather than discussing the

diversity of the internalized learning outcomes, I explore here what kinds of significant changes

have occurred in the students' life as the results of the activities.

The activities at PACHS and Whittier were conceived to solve the problems of their

community. Consequently, the results of the students' inquiry were some form of change in the

respective community's situation. The students at Whittier Elementary School, for example,

changed the community dynamics. They shared the results of their inquiry in various forms so

that other community members were aware of the issues. They helped mobilize the community

in their efforts to remove trash in the Chicago River area. They organized a beautifying project

for the empty lot. These changes in the community were visible. From the project, the students

also changed themselves. The students had been only passive residents of the community, but

they were becoming active participants who were making significant changes. They had been

studying civic responsibilities, but now they were exercising their own responsibilities through

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the inquiry. They had been learning about scientific literacy, and now they were building and using their scientific knowledge to solve important problems.

On the other hand, the activities at Dewey's Lab School didn't induce such radical changes in the community's situation. Because the students' inquiry was mainly to simulate social activities, the students didn't make any direct changes in problems outside school through their school activities. The focus remained on what students were learning for character and cognitive development. It is interesting to note that the school activities didn't contribute to changing any immediate problems in the community, though Dewey strongly believed that schools should contribute to individual and social change. Instead of overseeing the school activities to make active changes in their social life, he often talked about social change in the future tense, envisioning the effect of education *after* the students grew up to be responsible citizens (Benson et al., 2007). This is ironic, considering Dewey's emphasis on (a) the futility of preparing for the future without addressing the present concerns, and (b) the consequences of inquiry as a transformation of the problematic situations.

Issues of Inquiry-Based Education and Educational Goals

I started this study by questioning the meanings, values, and effects of inquiry-based education in our students' lives. What constitutes inquiry-based education? What do we mean by connecting students' experiences with science learning? What do we want to achieve when we engage our kids in science activities? What do we value as meaningful inquiry learning experiences? How are we helping students to have educative learning experiences?

The answers to these questions seemed so obvious with the innovative vision of inquiry for scientific literacy and with the strong support given by the education community. However, my analysis of the Standards and the four inquiry-based school activities revealed there are great

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differences in understanding the meanings and the means of inquiry-based education. In some cases, it was understood as engaging students in interesting hands-on materials to teach scientific processes. Sometimes, it was a collaborative group work to build independence and democratic attitudes. Other times, the teachers saw it as a dynamic, problem-solving process to change the community and the students' identities. Depending on the educational goals, different learning outcomes arose, such as getting familiar with science concepts and skills; developing students' positive social identities; making changes in the community through community action.

Despite the successes, none of the cases worked to fulfill the basic tenets of inquiry-based education—engaging students in meaningful, relevant, and participatory learning. For example, while we argue the importance of relevance and contextual authenticity for students' learning, we ignore students' own questions in the attempt to teach scientific inquiry. Although we recognize the diversity of experiences and the importance of students' initiatives, we design science tasks ourselves and expect students to participate in the way we assigned them to do it— otherwise, we label them as troublesome or lazy. While we believe inquiry activities should show the connection of school learning to students' experiences in life, we channel out the students' real concerns, such as race, sex, and friends from school discourses as nonacademic or irrelevant.

Different from the common analysis of inquiry-based education, I found the major dilemmas of the four cases did not stem from the teachers' improper implementation of inquiry or inadequate learning materials. They didn't arise from the lack of their commitment as teachers, their scientific knowledge, or resourcefulness. Rather, they were a manifestation of our educational values within the structure of the school—the rigid distinction between science as subject matter and students' ordinary experiences; the priority to students' academic performances over their social identity development; the separation of scientific discourse from

everyday sense making; the focus on inquiry of process instead of an inquiry of substance; the distorted continuum of present and future experiences; the institutionalized authority of teachers or standards over students' learning; and the disconnection of our schools from the society.

These issues were formidable, and it seemed unreasonable to pursue inquiry-based education as Dewey envisioned—a vision Dewey himself couldn't fully implement. However, from the analysis of the four cases, I have seen how different educational goals work to find ways to overcome the difficulties and produce different educational consequences. Yes, we know most current realizations of inquiry-based education are not perfect. Yes, inquiry-based education doesn't always work to draw students' participation and achieve the educational goals. Yes, it is difficult to implement inquiry-based education. Yet, we will not give up on inquiry-based education because it is the only way we can genuinely help students become reflective inquirers and grow to their fullest. In order to make inquiry-based education work under the current educational system, we need to do more than fine-tuning teacher education or developing more curricular materials. We have to engage ourselves in a thorough conversation for a radical change—redefining the ultimate ends and means of our school education to truly embody the ideals of inquiry-based education.

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