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UNIVERSITY OF CALIFORNIA, SAN DIEGO
CALIFORNIA STATE UNIVERSITY, SAN MARCOS

Problem-based Science Inquiry:
Challenges and Possibilities for Addressing 21st Century Skills

A dissertation submitted in partial satisfaction of the
requirements for the degree of Doctor of Education

in

Educational Leadership

by

Nahid Nariman

Committee in charge:

University of California, San Diego

Carolyn Huie Hofstetter, Chair
Janet Chrispeels, Co-Chair

California State University, San Marcos

Katherine Hayden

2014

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The Dissertation of Nahid Nariman is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Co-Chair

Chair

University of California, San Diego

California State University, San Marcos

2014

DEDICATION

I would like to dedicate this dissertation to my mother, Simin, who believed in me and transferred her love of knowledge to me, and to my daughter, Anahid, whose love kept me warm and her constant support and edits made this possible. Also, to my husband, Seyfi, the true love of my life who has always supported me and without whom life becomes meaningless. Last but not least, to my son, Armin whose path is just beginning and I cannot wait to see where he goes.

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Chapter 4, in part is currently being prepared for submission for publication of the material. Nariman, Nahid; Chrispeels, Janet; and Karwan, Vanessa. The dissertation author was the primary investigator and author of this material.

VITA

Experience

TIDES, Transformative Inquiry Design for Effective schools and Systems

2011 - Present Director of Research

Solana Beach School District

2002 – 2011 Computer Resource Assistant – Staff developer

2000 - 2002 Computer Instructor

Del Mar School District

1998 – 2000 Computer Instructor

Education

2014 Doctor of Education, Educational Leadership
University of California, San Diego/California State University,
San Marcos Joint Doctoral Program

1990 Master of Arts in Education
University of Carleton, Canada

1992 Bachelor of Arts in Education
University of Ottawa, Canada

1980 Bachelor of Arts in Psychology
Shiraz University, Iran

Credentials

Multiple Subjects with Technology emphasis

PROFESSIONAL EDUCATIONAL PRESENTATIONS

Nariman, N., Chrispeels, J., Karwan, V. (2014). Problem-Based Inquiry: Innovation in Practice and Learning. Paper to be presented at the American Educational Research Association, April 3-7, Philadelphia, PA.

Hayden, K., **Nariman, N.** (2014). Probing innovative and effective online pedagogical practices: Faculty perceptions on the future of cybereducation. Poster to be presented at the American Educational Research Association, April 3-7, Philadelphia, PA.

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Nariman, N., & Chrispeels, J. (2013). Implementing the Common Core: Opportunities, Challenges and Innovation. Paper accepted for the 92nd Annual California Educational Research Association (CERA) Conference, December 5-6, Anaheim, CA.

Nariman, N. (2013). Challenges and obstacles of implementing Next Generation Science Standards: The experience of an elementary summer science school. Poster presented at the 20th Annual Conference of American Association for Teaching and Curriculum. Oct. 9-12, Chicago, IL.

Nariman, N., Chrispeels, J., Karwan, V. (2013). Inquiry Designs for Deep Learning: Moving to Student-centered Classrooms to meet Next Generation Science Standards. Paper presented at the 26th Annual International Congress for School Effectiveness and Improvement, January 3-6, Santiago, Chile.

ABSTRACT OF THE DISSERTATION

Problem-based Science Inquiry:
Challenges and Possibilities for Addressing 21st Century Skills

by

Nahid Nariman

Doctor of Education in Educational Leadership

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Carolyn Huie Hofstetter, Chair
Janet Chrispeels, Co-Chair

This dissertation is a mixed methods exploratory case study on the implementation of problem-based inquiry. The trend of technological changes have

created a wave of global change, brought new understanding of learning, and requires a shift in education to develop and accommodate proficiency in 21st century skills and competencies. As a result, in many countries, including the United States, the push to benchmark educational standards is in place to prepare students for success in college and careers. The narrow nature of traditional teaching strategies that currently prevails in schools has been branded as one of the reasons for students' low performance. In particular, teacher-centered didactic instruction with the goal of preparing students for high stakes testing has led to a "teaching to the test" pattern rather than focusing on deeper understanding. This study argues that problem-based inquiry is a strategy that can help students gain and retain knowledge better and longer. Problem-based inquiry's promise of creating a rigorous academic environment in which all students can be engaged and involved, as well have the opportunity for a better understanding of learning materials and a fuller construction of knowledge is attained. Recognizing that knowledge is socially constructed, this study examined problem-based learning as the involvement of both teachers and students in the construction of their own knowledge. The overarching purpose was to examine if, by implementing problem-based inquiry, a school that followed a prescribed curriculum with a teacher-centered instruction approach was able to transform its teaching pedagogy to a more student-centered environment that focuses on student' success and prepares them for today's globalized high tech world. For this reason in Phase I eighteen teachers participated in semi-structured interviews, and in Phase II nineteen teachers participated in focus group interviews. Furthermore, selected classrooms and teacher collaboration meetings and classrooms were observed to explore the ease and benefits of its implementation, while probing its barriers. In addition,

teachers' lesson plans and students' work were examined to corroborate with interviews and observations data. This study offers recommendations to policy makers and educators in taking steps towards meeting the requirements for the Next Generation Science Standards.

CHAPTER ONE: INTRODUCTION

Students have long been the focus of research studies aiming to observe and better understand trends in their learning and achievement. However, since the mid-1990s this focus has taken an international spin. There are many organizations (The Organization for Economic Co-operation and Development –OECD; Trends in International Mathematics and Science Study –TIMSS; and International Association for the Evaluation of Educational Achievement –IEA, to name a few) interested in studying, evaluating, and comparing students’ performance to identify the way “globalization will change the world’s economies” (OECD, retrieved, November 20, 2012). The challenge that schools today are facing is how to best prepare students for our global society; this has been the impetus for the present study.

Context of the Problem

The evolution of technology has created a media-saturated and globalized world wherein people are more connected than in previous centuries (Darling-Hammond, 2010; Wagner, 2010). International reports testify that the globalized and competitive nature of modern society accentuates the need for students to master 21st century competencies in order to be successful in contemporary society (Darling-Hammond, 2010, 2007; OECD, 2010; Partnership for 21st Century Skills (P21), 2009; Wagner, 2010). High school graduates need to be armed with new sets of skills, which Wagner calls the *Seven Survival Skills* (2010). These skills include: critical thinking and problem-solving, collaboration across networks, agility and adaptability, initiative and entrepreneurialism, effective oral and written communication, accessing and analyzing information, and curiosity and imagination. Other researchers have emphasized the four C's:

collaboration, creativity and innovation, communication and critical thinking, and problem solving (The Acme Network, 2010; Medved, 2010). To ensure that more students are acquiring these skills, education and business leaders have not only called for more uniform and higher standards, but also that the American standards be internationally benchmarked (Achieve, 2010; Kohn, 1999). The goal of the new Common Core State Standards (CCSS), as well as the Next Generations Science Standards (NGSS) is to shift traditional teaching to a more student-centered approach with strategies that are able to instill 21st century competencies in students. It is anticipated that such a shift will enable students to be competitive in the complex global workforce (Darling-Hammond, 2010; Kohn, 1999; Christensen, Horn, & Johnson, 2011).

One might wonder why America should move toward internationally benchmarked standards. Quite simply, in a global economy, “the yardstick for success is no longer improvement by national standards alone, but how education systems perform internationally” (OECD, 2010, p. 3). Recently, American 15-year-old students ranked 22nd and 29th when compared to 65 other nations in science and mathematics respectively (OECD, n.d.). The data show that American students are lagging behind their peers in other nations in science and mathematics (Darling-Hammond, 2010; OECD, 2013, 2010). According to Partnership for 21st Century Skills (P21) (2009), the United States is among the world leaders in job growth in the fields of technology and telecommunication. Yet American graduates are not filling many of the jobs because they are not prepared to assume these positions. As such jobs continue to evolve, there will be increased demand

for individuals with the needed knowledge (math, science, and technology) and 21st century competencies.

The pressing matter is how U.S. schools will enact the proposed standards in such a way that they will support students' success and prepares them for today's globalized high tech world. Currently, with the ranking of the United States students in mathematics and science it seems that continuing with the same traditional teaching system will not enable students to acquire the desired competencies needed to be successful in today's global economy. This is a challenge faced by schools. New content standards have been established, but knowing the pedagogical approaches needed to help students meet these new standards is important. Also, the content and the professional development needed for teachers will play crucial roles. This study explored one pedagogical approach – problem-based inquiry -- as a teaching strategy that is capable of developing 21st century skills such as collaboration, communication, problem solving, and teamwork in elementary students.

Globalization and the Effects of Technology

All 21st century schools face ever-increasing demands to ensure that their students are well equipped for entry into colleges, the workforce, and citizenship (Darling-Hammond, 2010; Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011). Changes in society constantly affect the direction of education and have led to numerous educational reforms in the past. One of the elements in society that has changed in the past century has been the development of information and communication technology (ICT¹), particularly the World Wide Web. Human communications and connections have

taken a leap forward; rapid changes and advancement in the use of technology have led to booming economic growth and a demand on educational systems and schools to prepare students for the complex world of the future. Technology is an essential tool in today's learning that provides a link between the school, classroom, and outside world skills required for independent learning (Gibson, 2005; Gao, Wong, Choy, & Wu, 2010; Hattie, 2009; Lambert & Gong, 2010). Wilkins (2000) pointed out that literacy in math, science, and technology is a prerequisite for 21st century students' achievement.

The 21st century demands a literate populace for the future well-being of the economy. Yet the result of National Assessment of Education Progress (NAEP) (2005) attest to the lack of skills, such as higher-level reasoning and inquiry, needed for an information-generating and information-transforming economy in American youth. The 21st century society is highly dependent on science and technology, and the acquisition of the 21st century skills.

21st Century Competencies and Skills.

The rationale for formulating 21st century competencies. One of the reasons that 21st century education needs to be different from the previous century is the rise and development of ICT (Dede, 2009) and the creation of a new set of jobs requiring new skills (Warschauer & Matuchniak, 2010). Therefore, the first rationale for formulating new competencies in students is to prepare them for current and future workforce demands. In the past, technological skills were not part of job requirements; yet these skills now play an integral role in recruiting employees. The employment projection from 2002 to 2012 anticipated that 80% of the fastest growing occupations ask for

technological fluency (U.S. Department of Labor, 2006). Economists have observed a decline in jobs that are routine cognitive work or routine manual labor (Dede, 2009). Present jobs demand more expert thinking and the ability to complete other complex tasks that cannot be easily programmed by computers.

The second rationale for developing 21st century skills in students is the way ICT takes part in changing the nature of “perennial” skills and creating new “contextual” skills (Dede, 2009, p. 2). Some skills, such as collaboration or communication, are not new to this century. Nevertheless, with the use of ICT, collaboration has moved from face-to-face and across a table to cross-border interactions. Today, individuals can search for anything on their computers and instantly find digital data. But this overwhelming amount of information at individual’s immediate disposal can include incomplete, unrelated, or biased information. It is important to be able to filter through this information; these are 21st century skills have to be learned and teachers are the ones who need to instill these competencies in students.

The third rationale focuses on the need to shift the curriculum focus. An examination of the 20th century curriculum illustrated the current focus in the present curriculum and the need for future change. For instance, teaching to the test and the lack of professional development are two reasons why 21st century competencies have been underemphasized (Dede, 2009; Roschelle, Pea, Hoadley, Gordin, & Means, 2000). There is a great need for unlearning the “underlying schools’ industrial-era operating practices” and for a transformative relearning of 21st century competencies (Dede, 2009, p. 4). Educators and administrators will need to discern what part of the current curriculum

could afford to be deemphasized in order to find room to teach the essential 21st century competencies (Dede, 2009).

The final rationale for the formulation of 21st century skills comes from ICT and its application to the classrooms. By simply serving as a supplement to traditional styles of instruction and learning, technology is not fully realized (Roschlle et al., 2000).

Rather, it needs to be used as a tool to extend learning in new ways. While the advancement of technology has created a giant leap forward, and 21st century competencies need to be developed in every individual, the complex problems of implementing such changes will require knowledge, skill, understanding on the part of educators, and a political emphasis to support those changes.

Description of the 21st century skills and competencies. For students to be successful, new skills that have come to be known as “21st century skills and competencies,” are demanded (Darling-Hammond, 2007; Partnership for 21st Century Skills, 2009; Wagner, 2010). The Partnership for 21st Century Skills (P21) advocated for the implementation of 21st century interdisciplinary themes such as global awareness, health, civics, environmental, and financial literacies in the core school subjects (2009). In the same fashion, a 2007 joint report of P21, along with the State Educational Technology Directors Association (SETDA), and the International Society for Technology Education (ISTE), envisioned 21st century teaching and learning as focusing on raising students who are *critical thinkers*, *problem solvers*, and *innovators*. There is increasing need for students as well to learn about contemporary issues such as global awareness, economic/financial, health, and environmental literacies. Schools and

educational leaders are faced with the challenge of preparing students with core knowledge skills and also ensuring that they are armed with the skills for a competitive world. It is the role of educational leaders to create an environment where these skills are taught equally to all students; thus, student needs for competitiveness in a global arena can be satisfied. Moreover, Mid Continent Regional Educational Laboratory (Lauer, Stoutemyer, & Buhler, 2005) also recognized cultural awareness; productivity, self-direction and ability to collaborate; technology literacy (e-communications); global awareness; and leadership skills as key components of 21st century skills. To acquire 21st century skills, students must be encouraged to create new ideas, gather information, analyze the data and compare it with their previous experiences, and last, to learn from them all. ISTE (2008) developed a set of six basic skills that students need to acquire in an increasingly digital world. These skills include: creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving and decision making; digital citizenship; and technology operation and concept.

Other educators have emphasized the inevitability of developing and possessing essential skills by all learners. Students who are graduating from American schools have to possess 21st century skills to be able to compete for job opportunities that now require a higher level of skills, especially technological skills. This means that defining the knowledge, skills, performance, and dispositions needed for 21st century living is at the core of the change required in education to prepare the students for the global economy of the 21st century (Spires, Lee, Turner, & Johnson, 2008). Schools and educational

systems need to be aligned with 21st century living, and this alignment should match the objectives and goals of these frameworks, emphasizing that students need to learn the core subjects *in addition to* 21st century skills to be successful. At the same time, P21 believes that schools or districts should offer support through challenging learning environments, standards, assessments, curriculum, instruction, and professional development. Once this support is in place, the resulting outcome will be the skills, knowledge, and expertise that students need to succeed in the 21st century (2009).

In summary, there is considerable overlap among various frameworks. Although each of these frameworks has developed independently with wordings of their own, they share multiple common concepts with many overlaps among them. All tap into the importance of moving beyond teaching solely core subjects and toward teaching the skills that will produce well-rounded students, using strategies that move towards engaging students in their own learning. At a minimum, students need to have information and communication skills, interpersonal, collaboration, and self-directional skills to work as part of a group, and well-developed thinking skills and problem-solving abilities.

Statement of the Problem

Given that American students are lagging in math and science in international comparisons, and both higher education and employers are convinced that students are graduating without the skills needed to be successful in college or careers, there is a need to rethink and retool American education (Dede, 2009). As Wagner (2010) has asserted, it is not that teachers and the system are failing as much as it is that the system is obsolete because it has not changed with the needs of our time. For survival and success in the

global marketplace, a critical ingredient is access to an education that teaches collaboration, critical thinking, creativity and problem-solving inquiry (Wirth, 1993, p. 364).

The major assumption here is that traditional teaching methods are not providing the vital framework, strategies, and time needed for deeper learning to occur. A shift from a focus on factual learning to ensuring that students are able to interpret, evaluate, apply knowledge, and solve problems is needed. Despite the fact that educators are trying to emphasize the ability of technology to transform teaching and learning (Bransford, Brown, & Cocking, 2000), a shift within the current education system to accommodate such changes has not yet taken place (Dede, 2009). Reinventing schooling to meet the demands of today's global, flat, and high-tech world is a huge challenge that many educational systems are just beginning to tackle. Contrary to traditional education, where the emphasis was on memorization, recent research demonstrates that it is the structure of the knowledge domain that guides both teaching and learning.

In their handbook for project-based learning, Markham, Larmer, and Lavitz (2004) introduced design-based, collaborative work in classrooms as a powerful learning method that teaches students 21st century skills. Knowing that 21st century competencies refer to the growing global movement that has participated in redefining the goals of education and how learning and teaching is practiced in everyday life, Oxford (1997) believes that teachers need to design a curriculum around a theme-based approach where these skills are considered as part of the content area. In another study, Lerman and Hicks (2010) have focused on the ability of technology in this transformation through

communication, collaboration, and creativity by exploring how Google applications can help teachers. Also, various scholarly research studies (Barron & Darling-Hammond, 2010), policy proposals (NCREL, 2003; P21, 2004), and national commission reports (NCTM, 1989; NRC, 1996) have argued that in order for today's student to be prepared for tomorrow's workforce, they need to explore real-life problems (Cited in Barron & Darling-Hammond, 2010). When students are exploring real-life problems, they are more engaged and motivated. Therefore, it is educators who by asking "open-ended questions and posing intriguing problems engage children's imaginations and help motivate them to explore, discover, create, and learn" (Trilling & Fadel, 2009, p. 94).

Another assumption of this study is that with the advancement of ICT and its broad availability, it is crucial to use it and motivate students to navigate deeper into the learning of science through both scientific inquiry and technology-based learning. These changes pose considerable challenges for teachers as they work to shift their instructional practices from teacher-centered textbook-based instruction with a primary focus on teaching information and factual recall to student-centered analysis and the use and creation of knowledge from multiple sources. Weimer (2002) has identified five key areas that instructional practice needs to change at the university level in order to become a learner-centered pedagogy. These five key areas include: the balance of power, the function of content, the role of the teacher, the responsibility for learning, and the purpose and processes of evaluation. These key areas can easily be translated into elementary teaching instruction, and they can be of value to this transformation.

Problem-based Inquiry as an Instructional Strategy for Deep 21st Century Learning

Since the early 1990s, research has focused on identifying skills and competencies students need to succeed in the 21st century (Marzano & Heflebower, 2012). Also, emerging is a growing body of research on the best instructional approach to teach these skills. Recent research has emphasized problem-based inquiry as one crucial learning approach (Azer, 2009; Belland, Ertmer, & Simons, 2006; Blumenfeld et al, 1991; Etherington, 2011; Hansen, 2006; Hmelo-Silver, 2004; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Tandogan & Orhan, 2007; Torp & Sage, 2002; Vardi & Ciccarelli, 2008). It is a pedagogical approach for moving towards creating more student-centered classrooms, wherein students are required to use critical thinking, problem solving, innovation, creativity, data analysis, and teamwork. This approach is receiving growing attention among educators. Scholars who argue for more student-centered classrooms believe that learning is conceptualized as problem solving (Murray, Olivier, & Human, 1998; Bransford et al., 2000; Newell & Simon, 1972); as inquiry (Dewey, 1902); as sense-making (Piaget, 1962); and as intellectual socialization (Vygotsky, 1978) (as cited in Roschelle et al., 2000, p. 94).

When learning is considered as problem solving, the focus shifts to finding the appropriate instructional approach to use. Problem-based inquiry is one pedagogical approach that shows promise in better meeting the needs of today's students and preparing them for an information-rich, global society. It is a pedagogical approach that engages students to actively participate in their own learning at all levels of education working, either individually or in small groups, on solving real problems and moving

towards their own understanding and achievement of concrete outcomes (Gültekín, 2005; Moursund, 1999) and for the shift from a teacher-centered learning environment to a student-centered one.

Research shows that to be ready and equipped with 21st century competencies, students need to be exposed to teaching strategies that actually engage them in communication, collaboration, creativity, critical thinking, and teamwork. Well-designed problem-based inquiry units have been shown to engage students in deep learning, problem solving, and critical thinking (Gültekín, 2005; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Marx et al., 1997). Research also suggests students learn and retain information better and longer when they are actively engaged in their own learning and in an environment that is designed to motivate them while receiving instruction from teachers who are facilitators of learning. When students work in collaboration and in teams, they play a key role in their own learning through active participation and creation of their own outcomes. As Hmelo-Silver, Duncan, and Chinn (2007) suggest, “There is growing evidence from large-scale experimental and quasi-experimental studies demonstrating that inquiry-based instruction results in significant learning gains in comparison to traditional instruction and that disadvantaged students benefit most from inquiry-based instructional approaches” (p. 104). Boothe, Vjaughn, Hill, and Hill (2008) have explored the positive effects of problem-based inquiry on language acquisition for the English Language Learners (ELL) students. Also, students of teachers employing problem-based inquiry in the teaching of science outperformed other students who were not exposed to such instruction (Johnson, Zhang, & Kahle, 2012).

However, schools face several challenges in implementing problem-based inquiry. First, teachers feel enormous pressure to cover the curriculum and prepare students for year-end standardized tests. Although problem-based inquiry is more effective in long-term learning gains, “coverage” can be a challenge, as problem-based inquiry units often take longer to implement. Second, during the last few decades the heavy focus on textbook-based curricula has not equipped teachers to make the transition to problem-based inquiry. They have little time and experience in collaboratively designing inquiry units and often little experience in facilitating group work. Third, because great emphasis and large time blocks are devoted to literacy skills, teachers feel there is insufficient time in the school day to engage in problem-based inquiry (The National Academies, 2005). The adoption of the Common Core State Standards and the Next Generation Science Standards offers an opening for teachers to begin rethinking instruction, as these standards will require students to become critical thinkers and problem-solvers in order that they may do well on the assessments.

Purpose of the Study

The purpose of this study was to explore both the challenges and benefits of implementing problem-based inquiry in science lessons to assist teachers in transitioning to a student-centered inquiry classroom. Thus, it explored the challenges teachers encountered in implementing this strategy. This exploratory case study documented, described, and analyzed elementary teachers’ experiences in implementing problem-based inquiry in science classes and used data from two phases. Phase I data came from

a collection of extant data from an Extended Learning Time (ELT) research conducted in summer 2012. Phase II data was collected during the summer of 2013.

Research Questions

This study investigated the following research questions:

1. What challenges do teachers face in shifting from a teacher-centered didactic approach to student-centered teacher facilitated learning?
2. What are the benefits of shifting from a teacher to a student-centered approach?
3. How do teachers stimulate inquiry and enable students to generate their own questions?
4. In what ways do student perceive they were engaged in generating their own questions?
5. In what ways do the IDDL Inquiry Prompt Process and the incorporation of the 5E model support student science inquiry?

Theoretical Frameworks

The lenses of constructionism (Papert, 1991), distributed cognition (Hutchins, 1995a, 1995b), and Rigor/Relevance Framework guided the data collection, analysis, and interpretation for this study. Both theoretical constructs drew on concepts of how people learn (Bransford et al., 2000) and viewed learning as a reconstruction of knowledge rather than solely a transmission of knowledge. One 21st century advancement has been in better understanding cognition –the mental process that is involved in thinking, gaining knowledge, perceiving, comprehending, and remembering. Children’s learning is most

effective when cognition develops via active engagement, participation in groups, frequent interaction and feedback, and connection to real-world contexts (Roschelle et al., 2000).

Constructionism Framework

This study's theoretical perspective was based in constructionism that is multidisciplinary in nature, drawing its influence from philosophy, psychology, and sociology (Kang, Choi, & Chang, 2007). Constructionism posits that individuals are constantly constructing the reality of their world and that most knowledge is constructed in and through social interaction (Spodark, 2005). This social construction of reality is an ongoing and dynamic process, and it is driven and maintained by social interactions (Berger & Luckman, 1967; Esterberg, 2002; Wheatley, 2007). "Constructionism" in action consists of 'building knowledge structures' irrespective of the circumstances of the learning" (Papert, 1991, p.1). Both students and teachers engage in the process of constructing and reconstructing their own knowledge through the use of problem-based inquiry, which creates opportunities for engagement, critical thinking, investigation, and discovery (Crawford, 2000; Burke, under review).

Distributed cognition

The distributed cognition theory developed out of ethnographic studies of airline cockpits and ship navigation (Hutchins, 1995a, 1995b). The result of Hutchins' study of the navigation team, for instance, identified how completing a cognitive task involved using harmonized actions as well as specialized navigation tools to accomplish a job that was not possible to be done by any single individual (Hollan, Hutchins, & Kirsh, 2000).

This means that a coordination of activities is necessary, not only between the people and artifacts, but also across an ingrained culture. Contrary to traditional approaches, distributed cognition stresses the social aspects of cognition. The distributed cognition theory provides a framework for exploring how cognitive activities are distributed across groups, space, time, and artifacts (Hollan et al., 2000). For the purpose of this study, both constructionism and distributed cognition provide a framework for exploring how teachers and students interact throughout an inquiry-based science unit.

Rigor/Relevance Framework

Daggett (2005, 2008) argued that the education system in the United States has not kept up with the changing nature of work, enhancement of technology and the competitive job market despite all the efforts educators make. He identifies the measure of academic excellence as a mean to provide state assessments through giving a score to individual students will not help our students in their competition to fill the available jobs. The No Child Left Behind (NCLB) Legislation Act created a pressure for all educators to get their students to the minimum proficiency levels. Daggett (2005) values the state assessment but not as a finish line, rather, he believes “if curriculum, instruction, and relevant learning become focus, the tests will take care of themselves” (p.1). This has led the International Centre for Leadership in Education (where Daggett is the founder and the president) to create the Rigor/Relevance Framework to examine curriculum, instruction, and assessment. This framework is based on two continual (Bloom’s knowledge taxonomy, and the application model developed by Daggett) represented by a four-quadrant model. With the emphasis this framework puts on making

changes in curriculum and assessment, I have used it to evaluate teachers effort in this study in creating a problem-based inquiry environment, and in leading to students learning improvement.

Methods

This study employed an exploratory case study to investigate the implementation of problem-based inquiry and its challenges and benefits (Yin, 2009). A case study, by definition is an investigation of a definite phenomenon (Merriam, 1988; Yin 2009) or an exploration of a “bounded system” or a case...over time through detailed, in-depth data collection involving multiple sources of information rich in context” (Creswell, 2008, p. 61). “The bounded system, or case, might be selected because it is an instance of some concern” (Merriam, 1988, pp. 9-10).

Rationale for Selection of the Study Site

The Carmel Elementary School (a pseudonym) offered an excellent site for this study because this school was designated as underperforming and required to initiate a Turnaround reform process. The Turnaround model for this school required the district to select a new administrator who in turn replaced over 2/3 of the classroom teachers. All teachers in the district could apply for and all, including current teachers at the school, were interviewed for these positions.

As part of a requirement for the Turnaround process the learning time for students was increased through a summer school Extended Learning Time (ELT). For this reason, the school selected to extend student and teacher learning over a three-year problem-

based inquiry of summer school session focused on science. Data were collected in the second year of the program.

At the time, I was part of a research team² that started data collection. This specific case captivated my interest into further investigating, documenting, describing, and analyzing the outcome of problem-based inquiry implementation. Thus this site presented an excellent opportunity to explore how problem-based inquiry was implemented in the science lessons. When the results of that study were shared with the school staff and administration a new opportunity arose to continue the study during the implementation of the next summer of 2013.

Thus, a case study created an excellent environment for collecting a variety of data including: surveys from students and teachers, observation notes, and interviews. Therefore, the method of data collection for this study consisted of two phases involving mixed methods. Both phases of data collection used data from quantitative and qualitative methods and multiple sources (See Figure 1.1). I interviewed all eighteen teachers to add to the qualitative data available from Phase I. Because of the team effort and individual work, I had access to a wealth of quantitative and qualitative data to explore, analyze, and describe the outcomes of the phenomenon under study. Therefore, the extant data available to me for analysis in Phase I included: a mirrored pre and post students' teamwork survey. Qualitative data for this phase included: classroom observation notes, teacher lesson plans, and student work samples of formative assessments and final products.

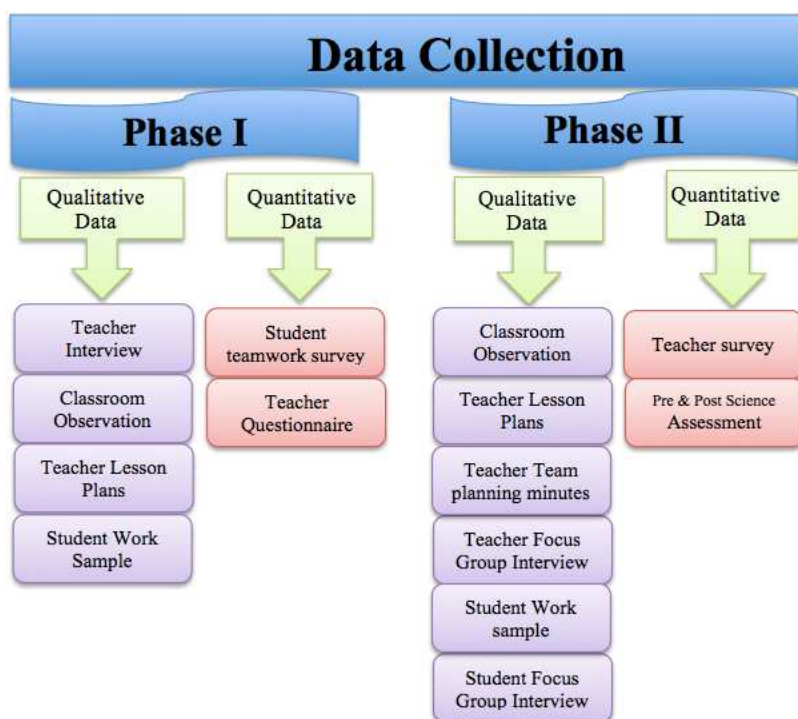


Figure 1.1. Phase I and Phase II of Data Collection

In Phase II, quantitative data included: a mirrored pre and post NGSS aligned student assessment, and teacher survey. Qualitative data for Phase II included: classroom observation notes, planning materials such as teacher weekly lesson plans, and collaboration and team planning minutes that were posted each week via Google Drive and later made accessible to me. Integration of quantitative and qualitative approaches of data collection created a comprehensive image of the experiences of teachers' efforts in implementing problem-based inquiry strategy and illustrates the challenges they encountered and the benefits they observed.

Significance of the Study

Both the CCSS and NGSS place more emphasis on science and scientific inquiry. The NGSS emphasizes “deeper learning,” ensuring that students are able to apply what

they know (National Academy of Science, retrieved, Aug. 15, 2012). In an effort to create internationally competitive students, steps have been taken to change the standards in place. The next phase would be implementing instructional strategies that enhance students' learning in Science, Technology, Engineering and Mathematics (STEM) disciplines and at the same time provide students with multiple opportunities to learn and practice 21st century competencies that play a major role in their futures in society. Many elementary school teachers have limited backgrounds in science and are using instructional practices that have not been effective; especially in under-performing schools serving high needs students, where the focus primarily is on teacher-centered didactic instruction. They will face challenges as they work to meet new instructional demands.

This study contributes to a better understanding of these challenges. It strived to find the reasons behind challenges teacher's faced in implementing problem-based inquiry for science instruction. Findings from this study have the potential to impact school practices and reforms. Also, the results of this study contribute to the larger field of education in several ways: (1) it highlighted how teachers and students go about taking the first steps moving towards inquiry learning, (2) it identified the challenges and benefits teachers encounter as they work to make the shift to a student-centered inquiry classroom, (3) having students generate questions revealed to be a tool that can easily be used by teachers in implementing problem-based inquiry, (4) the combined use of the inquiry prompt questioning process and the 5E learning model instructional model were powerful processes for guiding both teachers and students in engaging in problem-based

inquiry units that were aligned to NGSS, (5) by identifying powerful professional development that support teachers in their journey, and (6) the study theoretically explored how constructionism, distributed cognition theory and the Rigor/Relevance Framework provided a basis for understanding the learning process that occurs in problem-based inquiry classrooms. This information will be particularly useful to school leaders, practitioners, and policy makers in identifying what are the support and professional development needs for teachers.

Definition of Key Terms

Common Core State Standards (CCSS): Contrary to the past where each state had its own standards, CCSS are shared across each state to give students an understanding of what is expected from them. CCSS are the first attempt to create a rich and succinct framework to prepare students for college and career. This is possible by emphasizing rigorous competencies, skills, and knowledge of English Language Arts and Mathematics that students need to learn to be academically successful. Forty-eight states, two territories, and the District of Columbia adopted CCSS by 2010.

Constructionism: The key emphasis of constructionism is to reveal how individuals and groups take part in constructing their everyday reality. The idea is that “knowledge is not simply transmitted from teacher to student, but actively constructed by the mind of the learner” (Kafai & Resnick, 1996, p. 1).

Distributed cognition: As a branch of cognition science, distributed cognition argues that cognition is not narrowed to an individual; rather it is distributed across individuals, space, artifacts, and time. Its proponents maintain that distribution of cognition extend to

social interactions, material settings and across time. More specifically, it is interaction with one or more technologies, started from interactions among people or the usage of the products from the past.

Next Generation Science Standards (NGSS): These standards are based on the K-12 Science Education Framework developed by the National Research Council. NGSS are collaborative, state-led efforts in creating K-12 science standards that are not only rich in content, but are also internationally benchmarked. In order for students to be college and careers ready, they need to master these standards (www.nextgenscience.org, Retrieved, Aug. 29, 2012).

Problem-based inquiry: This is defined as an “instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to defined problems” (Savery, 2006, p. 12).

Technology: In this study technology is defined as a piece of equipment that students have access to either at school or at home to use as a tool to gather information. This includes equipment such as: camera, video, projector, sound recording equipment, desktop computer, laptop, smart phone, iPod, or iPad.

Endnotes

¹Throughout this dissertation ICT and technology are used interchangeably.

²Transformative Inquiry Design for Effective Schools and Systems (TIDES) is a non-profit organization located in San Diego that thrives to transform educational system by partnering with school districts and engaging key stakeholders (superintendent, principals, and teachers) in inquiry towards building effective schools for 21st century learners. The researcher, as part of TIDES research team, participated in conducting a research on the implementation of problem-based inquiry during the summer of 2012.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

The intent of this literature review is twofold. First, it will provide a basis to review the past literature. Second, it will use past literature review as a foundation to discuss the structure for the present study. This literature review begins with an exploration of the historical development of learning and traditional beliefs on how children learn. It will then investigate the conceptual basis of schooling and current educational needs for students' success in the United States. Traditional and didactic instruction will be investigated to provide a comparison base for the discussion on problem-based inquiry. Then, problem-based inquiry will be explored deeper as the decisive instructional pedagogy that can help students to attain competitive 21st century competencies. Last, the theoretical framework for the present study is discussed. For this purpose, the theoretical constructs of constructionism and distributed cognition that underlie many current studies are explored and used to frame this study.

Introduction

As discussed in Chapter one, three primary forces are demanding and shaping changes in American education: technology and globalization, the nature of the learners who are entering our schools, and the demand by business and higher education for students to develop new competencies more in alignment with critical thinkers and problem-solvers. Figure 2.1 captures these three forces and shows how they relate to the three bodies of literature that will be reviewed in this chapter. This figure provides a visual for understanding the rest of the chapter. It implies that before arriving at the theoretical framework discussion, there are three major interconnected secondary forces pressuring 21st century schools that need to be reviewed. These secondary forces include:

the historical development of the research on learning and current understanding of the way children learn; new standards such as Common Core State Standards (CCSS) and the Next Generation Science Standards, which require schools to retool and rethink education; and, an effective teaching strategy, namely, problem-based inquiry, which aligns with the way children learn and the demands of the new standards.

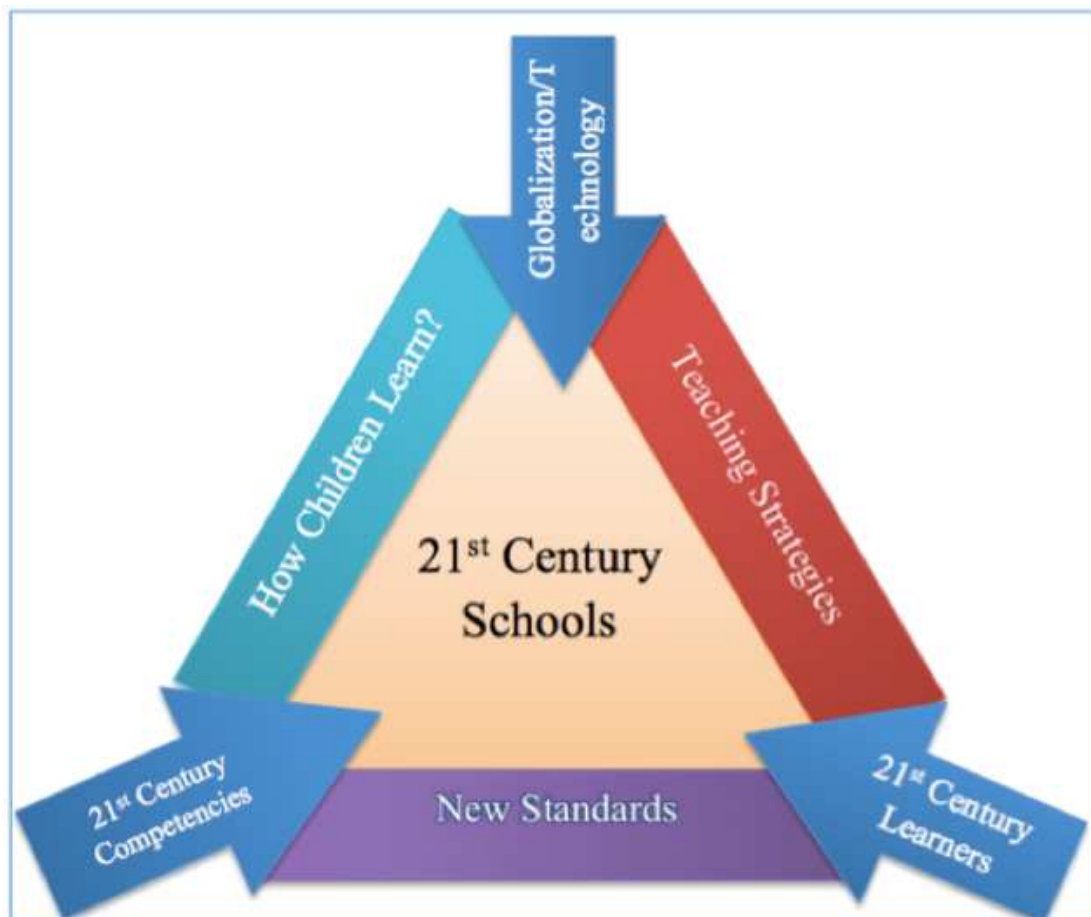


Figure 2.1. Visual Representation of Primary and Secondary Forces Affecting 21st Century Schools

Historical Development of Learning and the Way Children Learn

Children's learning is a complex topic. While a curiosity for learning and methods of influencing it have been around for centuries, the systematic study of learning

started in the early 20th century (De Corte, 2010). The evolution of the study of mind and brain, and the process of thinking and learning, has increased in the last few decades (National Research Council –NRC, 1996). Due to five current political and educational changes, Dumont, Istance, and Benavides (2010) argue that over recent years, learning has moved center stage across many countries. These five changes include: a profound transformation from reliance on an industrial to a knowledge base society, a strong focus on measuring learning outcomes, the sense of reaching the limits of educational reforms and the need for a fresh focus on education, the rapid development of information and communication technology, and a growing research base.

In recent decades, advancement of technology and the move towards globalization have been the fundamental changes shifting societies from an industrial to a knowledge base (Dumont, Istance, & Benavides, 2010). This transformation and an emphasis on knowledge have created a substantial demand for 21st century competencies. This demand has called attention to the quality and quantity of learning occurring in classrooms, with the concern that traditional approaches of learning are insufficient (Dumont et al., 2010; Hargreaves & Shirley, 2009; Kohn, 1999). As a result, researchers believe that there is a need for transformation in schools to change them into 21st century environments for learning. This is a transformation moving away from the early 20th century views of education and learning.

In the early 1900s, behaviorists' understanding of learning dominated thinking and education in the United States (De Corte, 2010). To behaviorists, such as Thorndike (1922), all human activities, including thinking, feeling, and acting, were considered behavior. Therefore, learning occurs when a behavior is reinforced through stimulus-

response connection. The basic idea of the behaviorist perspective implies that “learning consists of a change in behavior based on the acquisition, strengthening and application of associations between stimuli from the environment ...and observable responses of the individual” (De Corte, 2010, p. 36). In other words, learning occurs as a response to environmental stimuli. Learners were taken to be passive recipients of knowledge, and textbooks were the preferred methods of instruction. Skinner’s later radical or selectionist behaviorism theory inherits from behaviorism the idea that animals’ behavior can be studied and further compared to human behaviors. Skinner, following the behaviorists’ philosophy, emphasized the environment as the cause of behavior and focused on operant conditioning. His selectionist model identifies behavior as evolving or selected by the environment (Magliaro, Lockee, & Burton, 2005).

Concurrently with behaviorism, Gestalt psychology and the Würzburg School of the psychology of thinking were also predominant in Europe. These schools, contrary to their behaviorist counterparts, did not consider psychology as the science of behavior. Rather, they believed that the organized whole is more than the collection of its parts. Thus, learning consisted of “gaining insight, discovering a structure, and hence of acquiring understanding” (De Corte, 2010, p. 36). The Würzburg School, for instance, emphasized the study of thinking and problem solving. Therefore, deep thinking depended on using appropriate solution methods and involved using specific methods for solving specific problems.

In the late 1950s, an important change in American psychology known as the “cognitive revolution” developed (De Corte, 2010, p. 38). This revolution brought a shift from behaviorism to cognitive psychology, a theory that posited individuals are an

assembly of responses to external stimuli. They were perceived as information processors. Of course, Gestalt psychology and the Würzburg School, along with the emergence of computers as an “information-processing device,” were influences on the shift to cognitive psychology (De Corte, 2010, p. 38). Learning, for cognitive psychology, was seen as knowledge acquisition: individuals exposed to diverse information absorbed the information, and through some cognitive operation in their minds, could save the information to memory (De Corte, 2010). Thus, the cognitive psychology movement brought a fundamental change by emphasizing the central role of information processing and knowledge acquisition in individuals.

During the 1970s and 1980s, as a result of numerous research studies on human learning and thinking, an idea emerged that humans are not passive recipients of information, but rather they actively participate in the creation of their knowledge. The focus was on the learner as a sense-maker (De Corte, 2010). Research influenced by the work of Piaget (1962) and Bruner (1961) resulted in the advent of constructivism. According to constructivism, learners actively participate in constructing their knowledge. Contrary to Gestalt psychology, which saw learning as a recording of the information, constructivism viewed learning as interpretation of information and knowledge construction.

In the late 20th century, the constructivist perception of learning was revised to take into consideration the impact of context and social action (Kafia & Resnick, 1996). Of course, it was heavily impacted by the work of Russian psychologist, Vygotsky. Piaget’s view led to constructivism and Vygotsky, who lived at the same time as Piaget, offered a broader conception of constructivism. His view differed from Piaget’s view in

the sense that he believed learning leads to development. This is contrary to Piaget, who believed that development leads to learning. To Vygotsky, children collaborate in co-constructing their own knowledge. But, at the same time, their learning is shaped by their surroundings, i.e., environment, community, people, friends, and family. That is why discussion of this theory all have social or cultural words included, such as sociocultural theory, cultural-historical theory, or social-historical theory.

There were two important factors in his vision. Vygotsky (1978) referred to scaffolding as instructional support teachers can give to students when they are learning new skills, content, or knowledge. In this way, the target objective will be reached through a set of sequential step-by-step skills that are broken down into smaller chunk for better acquisition. Learners' readiness for new knowledge is also facilitated through what Vygotsky labeled the zone of proximal development. This is a bridge between what learners can do on their own and what they are able to accomplish with another person's help (such as a teacher, friend, other classmate, or parents). The emergence of social constructionism, based on Vygotsky's work, emphasized the fact that learning happens during social interaction; in other words, it is shaped through participation and social negotiation.

During the last two decades, research studies on learning in education have focused on learning and teaching in real classrooms. This has made significant contributions to the understanding of student learning in various school subjects while at the same time helping to understand a variety of teaching strategies that have enabled effective learning.

Current Understanding of Learning. Bransford et al. (2006) differentiated among three main branches of research on learning: implicit learning and the brain; informal learning; and designs for formal learning and beyond. Implicit learning encompasses learning environments in which learning happens naturally and information is acquired without the individual's awareness. An example of this would be language learning in young children. Informal learning is a kind of learning that happens in a non-school setting, such as in playgrounds and museums. Designs for formal learning and beyond correspond with learning in both educational settings, such as schools, and "beyond," thus making a connection to informal learning activities (Bransford et al., 2006).

Another significant issue in the current understanding of learning is the acquisition of "adaptive expertise." An important goal for learning in different subjects is to acquire "adaptive expertise" or "adaptive competence," as compared to "routine expertise" (Bransford et al., 2006; De Corte, 2010; Hatano & Inagaki, 1986). A routine expertise entails the ability to do a set of complex routines skillfully and accurately (Bransford et al., 2006; Hatano & Inagaki, 1986), while adaptive expertise or competence is the "ability to apply meaningfully-learned knowledge and skills flexibly and creatively in different situation" (De Corte, 2010, p. 45). This means that adaptive expertise requires the individuals to stretch their knowledge and move away from their existing comfort zone (Bransford et al., 2006). To develop this expertise in students means helping them learn about themselves as thinkers and problem-solvers (Bransford et al., 2006) and, at the same time, encouraging acquisition of some cognitive, affective, and motivational components (De Corte, 2010). To lead students towards adaptive expertise

requires moving away from traditional teacher-directed and guided learning towards using novel classrooms practices. “School learning needs to be more ambitious than was traditionally the case in taking on additional objectives: it should be active/constructive, cumulative, self-regulated, goal-directed, situated, collaborative, and knowledge building” (De Corte, 2010, p. 47). This is what Bransford et al. (2006) call “design for formal learning and beyond” where the students stretch their adaptive expertise beyond their comfort zone.

Current Learners

Today’s students (born during the mid- to late-1990s) are referred to as Generation Z (McCoog, 2008; Walliker, 2008). They are also being called the New Millennium Learners (Dumont et al., 2010), Millennial Generation, Internet Generation, Net Generation, and/or Digital Native (Prensky, 2001). This new generation forms a cohort that is ready and prepared to respond to various and fast stimuli. Understanding how they play, learn, and socialize outside the classroom and school environment is essential to identify how they learn (Ananiadou & Claro, 2009). Digital media has transformed learning environments for these students by allowing them to network and to have access to information anywhere and at any time (Dumont et al., 2010). They are highly connected and very comfortable with using media technologies such as mobile phones, instant messaging, YouTube, Facebook, and Giigo, to name a few.

Technological advancement throughout the globe and its impact on our societies has created various non-formal learning situations for students that cannot be ignored. Many members of Generation Z are rarely found without their cell phones, most of which have Internet access. This generation is typically engaged in social interactions in the digital

context and readily available access to ICT has changed the way they obtain information and acquire knowledge. Today's learners, distinctive from previous generations, learn differently in that their learning is "highly social, involves a good deal of experimentation and 'tinkering,' and encourages the production and sharing of knowledge. Digital media facilitates learning that is more about interaction and participation and not the passive consumption of information and knowledge (Ananiadou & Claro, 2009 cited in Dumont et al., 2010, p. 25).

While digital communications come easy to Generation Z, they still need to learn how to change these tools from a piece of equipment (or entertainment) to an educational aid and tool. Teachers will need to change from traditional teaching methods to ways of teaching that put students in charge of their learning. So one needs to question how present-day schools are challenging and engaging Generation Z's minds. In the next section, I will provide a short review of traditional schooling and the need to move away from it and towards a system that helps to prepare students for the current and future job market.

21st Century Schooling

Perpetuation of the Traditional American School Model. Traditionally, schooling in the United States has been and continues to be under local control. There is no national curriculum, and the various states are in charge of their own curricular guidelines, teacher training, and graduation requirements (Milson & Kerski, 2012). The current U.S. education system is rooted in a traditional school system, in teacher-centered instruction where skills are drilled into students, academic fields are taught separately with a focus on "back to basics," there is an emphasis on 'obedience to authority.' In

addition, technology has not been fully recognized as an essential tool for learning (Dede, 2009; Kohn, 1999). In such school system, science was learned by reading science textbooks and through memorizing important terms (nextgenscience, retrieved, Aug. 22, 2012), with focusing on learning “what do scientists know.” Nowadays, the shift to Science, Technology, Engineering, and Mathematics (STEM) and incorporating more problem solving and critical thinking although inevitable, is hard because supporting students to get there seems to be somewhat problematic given our current educational system (Kohn, 1999).

As I mentioned in chapter one, the current focus of curriculum does not match the need for future changes. The traditional way of teaching needs to give way to the ones that put students in charge of their learning.

The Need to Modify the Traditional Schooling Model. According to Kohn (1999), traditional schooling is unproductive and unappealing with its worksheets, drills, and tests. Knowing that the “United States is standing still while more focused nations move rapidly ahead” (Darling-Hammond, 2010, p. 9) suggests that traditional schooling is one of the reasons students are not learning effectively (Kohn, 1999). The flaws in the present system call for a different kind of education, a kind that instills the competencies students need to prepare them for careers and college. A review of the literature in this area demonstrates that since the 1980s, the requirement for transforming the education system has stemmed from a range of organization and commission reports. This range of reports includes: the National Council of Teachers of Mathematics (NCTM) report (2009); National Research Council report (1996); North Central Regional Educational Laboratory (NCREL) policy proposal (2003); Partnership for 21st Century Skills (P21)

policy proposal (2004); and scholarly research, such as Kohn (1999), and Levy and Murnane (2004). All these reports, policy proposals, and scholarly works assert that learning should support “inquiry, application, production, and problem-solving” (Barron & Darling-Hammond, 2010) and should help students to acquire competencies that are nurtured in the real world through complex and meaningful projects.

Recently, Hargreaves and Shirley (2009) infer from their studies of the highest-performing systems that the best hope for education lies in “change” strategies. They sought to demonstrate that the old approaches to educational change are not well suited for the core changes of the 21st century. They have uncovered the strengths and limitations of change efforts in education since the 1960s believing that lessons learned from the past are important for positive and sustainable changes in the future. Also, they believe, uncovering flaws of past educational reforms provides a platform for their suggested “fourth way.” They advocate for keeping few qualities from each of the past educational change efforts. For instance, they suggest we keep inspiration, innovation, and autonomy from the first wave of reform; urgency, consistency, and all-inclusive equity from the second; and, balance and inclusiveness, public involvement, financial reinvestment, better evidence, and professional network from the third reform effort. Advocating for an educational reform such as the fourth way, Hargreaves and Shirley (2009) suggest keeping the best qualities from previous educational changes to create outstanding reform in student learning and achievement.

In short, the first step towards helping students become more competent in STEM disciplines starts from a few fundamental changes in the education system as a whole. Per Hargreaves and Shirley’s argument, (2009) education systems of the 21st century

need to be transformed by moving away from high-stakes testing into encouraging innovation and creativity through selecting critical instructional strategies.

The need for new schooling. The pre-digital learning environment is portrayed as a controlled environment with highly directed, focused, and limited resources. Despite the push toward the digital world, expectations and outcomes of schooling are still measured by the last-century standards. Not long ago, the role of the educational system was to prepare students who could academically achieve and help them to attain skills, knowledge, and behavior to succeed in an industrial society. Today, the age of industrialization has passed, and we have stepped into the knowledge/information/digital age where new skills are demanded (Hill & Hannafin, 2001). David (1994) defined the American educational system as an interlocking jigsaw puzzle. To be successful with introducing any transformation such as the use of technology, or to implement a new instructional strategy other than the traditional way, other pieces of this puzzle, i.e., teacher development, curriculum, and assessment need to be equally challenged.

The Trends in International Mathematics and Science Study (TIMSS) ranked U.S. students as 29th in eighth grade science and 35th in math in a comparison of 40 developed nations (Darling-Hammond, 2009). The Programme for International Student Assessment (PISA) has also ranked U.S. students at 22nd and 29th compared to 65 other nations in science and mathematics (OECD, 2013). Thus, American students are lagging behind their international peers in science and mathematics (Darling-Hammond, 2010, 2007; OECD, 2010, 2013). For U.S. students to be able to compete and thrive at the global level, they need to demonstrate strong foundations in mathematics and science because the employment opportunities are expanding in STEM-related disciplines

(Achieve Report, 2010). Coincidentally, U.S. students show a lack in applying their knowledge to real world skills; they lack the “adaptive expertise” mentioned earlier. Where to focus and how to introduce the required changes into the current schooling system is a pressing issue for current educational systems. This is not an easy task, as there is vast disagreement on this topic. In the next section of this chapter I will discuss three areas more closely: lack of science teaching and science standards, emergence of new standards, and the direct instruction strategy. This will lead my discussion to the problem-based inquiry and ways it can instill 21st century skills and competencies in students.

Lack of Science Teaching and Science Standards. A review of *No Child Left Behind* (NCLB) shows that when Congress passed this legislation in 2001, the expectation was that stronger accountability discourse would be brought into public education. The goal of NCLB was two-fold: first, to increase the academic performance of all children, and second, to reduce the achievement gap. NCLB focused on standardized testing to create a homogenous curriculum for various states (Cuban, 2008; Darling-Hammond, 2010). However, the false emphasis of ‘one-size-fits-all’ standardized testing and the shift towards high-stake accountability was so grave that it created a culture of ‘teaching to the test’ (Hargreaves, & Shirley, 2009). An unintended consequence of NCLB’s accountability and high stakes assessments is that science education has been put on hold or has encountered barriers such as limited time where minimal or no support is provided for teachers (Darling-Hammond, 2010; Johnson et al., 2012). Science was squeezed out of classrooms, especially elementary school classrooms, to make room for reading and math under the pressure of NCLB. The lack of

science instruction is particularly acute in schools serving high percentages of low income, diverse student learning English as a second language. A decade after NCLB, the abundant testing data provides proof of its failure in raising academic performance, narrowing the achievement gap, and preparing American students for the future job market.

Need for science learning. The recent development and changes in the growth of the economy have identified Science, Technology, Engineering, and Mathematics (STEM) disciplines as the cornerstone of an advanced society (National Research Council, 1996; National Science Foundation, 1999) and the demands for STEM competencies have increased steadily (Carnevale, Smith, & Melton, 2011). American students need to demonstrate strong foundations in mathematics and science because employment opportunities are expanding in STEM-related disciplines (Achieve Report, 2010). “At least 70% of U.S. jobs now require specialized knowledge and skills” (Darling-Hammond, 2010, p. 2). The nature of the workplace has also changed rapidly, as the top 10 percent of in-demand jobs of 2010 did not even exist in 2004 (Gunderson, Jones, & Scanland, 2004). Accordingly, to be able to compete for entry into the workplace in science-related disciplines, students need to have an education that emphasizes the development of competencies that are especially useful in learning and using science. Science education also plays a central role for all students as it is preparing them to become informed citizens. In the past, many competencies have not developed in students and one possible explanation for this problem is the limited or non-teaching of science. With the development of technology and the new directions in the job market, the teaching of science is of considerable importance.

Emergence of New Standards

In the following sections, I will review the lack of science standards and the need for having them. We cannot afford not to teach science anymore.

Lack of Science Standards. When it comes to science, there have been two critical concerns: the lack of science teaching and the lack of clear science standards to guide K-12 instruction. Presently, both the National Research Council (NRC) and the National Science Foundation (NSF) stress the STEM disciplines as the cornerstones of an advanced society and propose that the demands for STEM competencies have increased vastly (Carnevale et al., 2011). During the 1990s, in the United States, various national associations of educators started to create standards for different subject areas. For instance, the American Association for the Advancement of Science (AAAS) (1993) created benchmarks for science literacy; the National Council for the Social Studies (NCSS) (1994) worked on standards for social sciences; the National Geography Education Standards Project (NGESP) (1994) developed standards for geography; and the National Research Committee (NRC) (1996) developed the science standards (as cited in Milson & Kerski, 2012). The work by AAAS and NRC in science standards and literacy were used by various states to develop state science standards, although usage was limited. Still, these documents have aged, and advancements in the world dictated transformational reforms in the science education system to better prepare students for the competitive global workplace.

The Need for New Standards. The results of the international science assessment have directed science education communities to embark upon the task of developing a new science framework to replace old science standards, in response to the

workforce demands. This has primed initiation of educational reforms in various disciplines that will bring with them a set of shared standards that can be accepted by all 50 states to create an educational unity. One of those reforms is the adopted Next Generation Science Standards (NGSS). With an emphasis on ‘deeper learning,’ NGSS supports science instruction that is limited in number of core ideas but is explored in a greater depth.

To move towards the needed change in the STEM disciplines, and in science education in particular, NRC was in charge of creating a framework for the science standards and consequently, *Achieve*¹ aligned NGSS with that framework (Achieve Report, 2010). Contrary to NCLB that was a federal government initiative, NGSS is a state-led effort with no federal government involvement. It is based on the recommendations from National Research Council (NRC) and was partly funded by the Carnegie Corporation of New York. NGSS has moved into creating core ideas and practices in science. This move should reduce the burden on teachers who were covering many skills in the past and provide them a chance to focus on mastering fewer relevant skills. To develop these core ideas, the NRC used a set of criteria. In order for any idea to be considered as a core science idea, it had to meet at least two of four criteria. It had to:

- have a broad importance
- provide a key tool to better understand complex ideas
- be either related to life experience of the students or be connected to their societal concerns
- be teachable at various grade levels.

Additionally, after reviewing numerous science frameworks, standards, and benchmarks and the related research on teaching and learning of science, four domains of science (i.e., life sciences, physical sciences, earth and space sciences, and engineering and technology) were explored to create these core ideas. Students who are college and career bound need to master these core ideas to be successful in the future.

Moreover, to prepare students for the future job market and to set internationally accepted standards, *Achieve* examined ten sets of international standards for two reasons: to inform the conceptual framework of science and to develop the NGSS. These standards were selected from countries either based on their performance on the Program for International Student Assessment (PISA) and/or their “economic, political or cultural importance to the United States” (Achieve Report, 2010). The countries examined imposed certain requirements on their students, such as participating in integrated science instruction from primary school, providing multiple examples, having a clear organization and format, making connections to assessments, and developing students’ ability to use inquiry (Achieve Report, 2010).

In short, 26 states and several organizations collaborated in creating NGSS that went into effect in early 2013 and by the end of the 2013 nine states (Rhode Island, Kentucky, Kansas, Maryland, Vermont, California, Delaware, Washington, and the District of Columbia) have adopted it. Following CCSS, NGSS fulfills the second step towards helping students in their acquisition of needed competencies for the STEM disciplines. It also set the needed standards for science inclusion and calls for schools to arm students with problem solving, critical thinking competencies, and the ability to work collaboratively and cooperatively.

Traditional Way of Teaching: Direct Instruction

Rooted in the behavioral theory of B. F. Skinner, direct instruction has played a major role in schools since the mid 1960s (Magliaro et al., 2005). Direct instruction generally refers to instruction led by the teachers; it has a variety of general and specific meanings, both negative and positive (Rosenshine, 2008). Direct instruction, according to The National Institute for Direct Instruction (NIFDI), is a model of teaching that is designed to teach small learning increments and teaching tasks through well-developed and carefully planned lessons (NIFDI, n.d.). The basis for direct instruction is that clear instruction eliminates any misunderstanding while at the same time enhances and accelerates learning (California Department of Education, n.d.). Siegfried Engelmann and Wesley Becker applied the term direct instruction to a pedagogical model of instruction in 1964. They created this model at the University of Illinois at Champagne-Urbana under a Project Follow Through grant. They believe that correctly used, this instruction can improve academic performance. Various research studies have attested to the positive impact of direct instruction (see Fischer & Tarver, 1997; Forness, Kavale, Blum, & Lloyd, 1997). There is no valuing teachers' creativity with this model because it requires teachers to follow certain carefully prescribed instructional practices (NIFDI, n.d.). It is currently applied in most schools in the United States, Canada, and the United Kingdom. This is an explicit teaching of skill sets. In this system teachers lead teacher-centered classrooms where they stand in front of the class presenting standard-based materials according to the adopted textbooks by their school and district.

Direct instruction is not appropriate to teach all subject areas because it is an instructional strategy that is teacher-centered and lecture-based and teaches rules and

facts through question answer practice. Research shows that direct instruction has been effective in teaching basic skills, accelerated intervention cases, practices in special education settings, and for subject matters, such as reading, language arts, math, spelling, and writing. In other words, traditional teaching method or lecturing has shown to be a successful method of instruction when students are memorizing and rote learning, and in the instruction of high achiever students (Knight & Wood, 2005). It has been successful in such areas mainly because it encourages giving students information in sequential small pieces, and moving on to the next point only when they have shown understanding of the present point. Direct instruction does not negate the constructivist view that students construct learning meanings for themselves. Rather, with direct instruction, the teacher's role is to maximize students' active thinking on the topic. This means that it is based on full class instruction covering the first three components of Bloom's taxonomy. Students need teachers to explain exactly what is expected of them and to show them in details what steps to take to get there. Direct instruction classroom environments are competitive and teacher-controlled. The central purpose of this model is "promoting student on-task behavior through explicit instruction, ongoing support, and student engagement" (Magliaro et al., 2005, p 51).

During the last decade, new legislation has created a false emphasis at schools to prepare students for high-stakes testing. Daily focus is to prepare students for their bi-monthly benchmark assessments. These assessments are used as predictors of student performance on high-stakes standardized tests at the end of the year, and the results of these tests are highly valued. This leads to students' not being effectively taught how to think critically and apply what they have learned to new situations.

The Need for a Shift in Teaching Strategies

Along with the new standards comes the urgency to prepare students for the challenges of the future. To do so, we cannot emphasize and use methods of the past (Kohn, 1999). Currently the major issue of discussion among educators is finding the most effective method by which we can provide students with educational experiences that will lead to their success in the future (Hargreaves & Shirley, 2009). With NGSS, change has happened by identifying new standards, the next step is to introduce a shift in the teaching strategies from teacher-centered to student-centered. Research demonstrates that the most sought after 21st century competencies are not learned in isolation; rather, they are learned through interdisciplinary, integrated, project and problem-based activities. Teachers are required to implement classroom methods that help students develop the competencies identified as necessary for success in the 21st century. With the swell of e-learning, blogs, wikis, and online collaborations, teachers are no longer the only supplier of knowledge in the classroom. Teachers' responsibilities have expanded and transcended mere lecturing to include the role of a facilitator of learning in the classroom. Teachers need to coach, guide, and probe for deeper understanding, while supporting students' initiatives at the same time.

Problem-based Inquiry as An Instructional Strategy for Deep 21st Century

Learning. The educational system and society go hand-in-hand. In one organization – the educational system, students learn creativity and various methods of problem solving; these students are the same ones who will be the building blocks of society in the future. In traditional classrooms, students often have little opportunities to interact with each other, or even the teacher, thus leaving them without proper support for learning. The

ever-growing body of research on learning and appropriate instructional strategies confirms problem-based inquiry as a strategy that actively engages students in their own sense-making and knowledge-building journey (Garcia, 1993; Knapp, 1995; Braddock & McPartland, 1993). For the past 25 years, policy doctrines have promoted the use of inquiry in K-12 science (American Association for the Advancement of Science, 1990, 1993), and both CCSS and NGSS also emphasize the importance of inquiry in students' deeper learning. Although problem-based inquiry was developed in medical school, its spread to other education levels has proven to be useful, especially in the teaching of science.

In order to understand the reasons for why 21st century skills are important now, Barell (2010) suggests that we should look into the new and threatening domestic and foreign problems. He views problem-based inquiry as a strategy that helps students to explore and even begins to address these real world problems. When engaged in problem-based inquiry, students generally ask good questions, conduct investigations, draw conclusions, and reflect and comment on meaningful solutions; these are all strategies that align with the scientific process (Barell, 2010). Children learn best when they participate actively in the construction of knowledge through a combination of collaborative interaction, and experience with other classmates and the teacher (Roschelle et al., 2000). Problem-based inquiry is in complete support and agreement with various learning styles and that is why it leads to students actively engaging in the learning process. Students are not merely passive recipients of knowledge using this strategy (Barell, 2010). Problem-based inquiry also challenges teachers in reconstructing their own understanding of problem solving.

Not only do the roles of teachers and students need to be rethought, but also educational programs and their goals must be re-envisioned (Barell, 2010). Amongst the featured descriptions of problem-based inquiry is the initiation of the shift from a teacher-centered learning environment to a student-centered one. The emphasis should be on deep learning where students work individually or in small groups, and are encouraged to work on the real world problems. Tackling such issues will enable students to refine their own understanding and achieve more concrete outcomes (Moursund, 1999). Students who are taught with problem-based inquiry learn to brainstorm to solve problem and create new knowledge for themselves. Therefore, the new content knowledge is gained through solving the problem. There are several steps involved in the implementation of problem-based inquiry. This involves fewer instructional goals to be set, but the learning process demands very specific content knowledge and skills. Furthermore, problem solving techniques and problem-based inquiry provides support for structured collaborative knowledge building when it encourages the group members to communicate their ideas in various forms of questioning, statements or drawing conclusions. It is through participation in continual group discussions that members become aware of how to organize their knowledge.

In a meta analysis, Schroeder, Scott, Homer, Huang, and Lee (2006) investigated the effects of various science teaching strategies on students' achievement. They looked at 61 studies carried out in the United States between 1980-2004 and found a high effect size ($d=0.65$) for inquiry strategy. In another meta analysis of 140 studies that compared the effects of traditional science teaching strategies with alternative strategies, Wise (1996) found that alternative strategies are more effective and students who are taught

with those alternative strategies performed better. He found the inquiry-oriented instruction to be the featured characteristic of those alternative strategies and recommended inquiry approach as the predominant approach to teaching science.

Research also supports learning that occurs rapidly when students have frequent chances to apply what they have recently learned and also when they receive immediate and frequent feedbacks (Marzano, 2009). As part of the group involvement, students demonstrate an increased motivation towards learning, a deeper understanding of concepts and an increased willingness to challenge difficult questions.

When learning is conceptualized as inquiry (Dewey, 1902), problem-based inquiry is one pedagogical approach that shows promise in better meeting the needs of today's students and preparing them for an information-rich, technology driven and global society. According to NGSS teaching of science should be focused on a limited number of core ideas for students to learn in greater depth and problem-based inquiry is a promising approach to adopt for teaching science. It also engages students in communication, collaboration, creativity, critical thinking, and teamwork. Research suggests that students learn and retain information much better and longer when they are actively engaged in their own learning in an environment that is designed to motivate them with teachers who are facilitators, or *activators* (Fullan, 2013; Hattie, 2009) of learning. Gültekín (2005) found that problem-based inquiry makes learning “enjoyable, meaningful and permanent, and develops essential and important skills in students” (p. 553). When students work in collaboration and in teams, they play a key role in their own learning through active participation and creation of their own outcomes.

In short, to enable students to investigate, design, create, analyze, and evaluate as the NGSS propose, teachers need to make a shift from a teacher-centered learning environment to a student-centered one. As I conclude this section, I am reminded of an assumption of this study: that for today's learners, learning is social and they need numerous experimentations to produce and share knowledge. This emphasizes that learning is about interaction and participation and the problem-based inquiry is an instructional approach that can help teachers, schools, and districts make the shift to a student-centered learning environment.

Theoretical frameworks

The research process is the passage from theory into data (Esterberg, 2002). As a researcher, I theorized my research by developing a *sociological imagination*, i.e., “the ability to see individual issues within a larger social context” (Esterberg, 2002, p.4). My selected theory further helped to explain various sections of the social world that I was exploring. “One cannot properly implement a study without a guiding theory” (Kawulich, 2009, p. 40). It is this guiding theory that determined the type of things of interests to me and the type of questions I asked (Merriam, 1998).

Building a framework for this research project involved a coordination of both distributed cognition, constructionism perspectives, and the use of Rigor/Relevance Framework. Thus, the theoretical grounding for this study was borrowed from: constructionism and distributed cognition and ran against the Rigor/Relevance Framework. Constructionism posits that as individuals, we are constantly constructing the reality of our world. Distributed cognition theorizes that knowledge is distributed amongst individuals, tools, space, and artifacts.

Constructionism Framework

Historically, the theoretical framework for learning has traveled from behaviorism to cognitive psychology, and from constructivism to constructionism (De Corte, 2010). Therefore, constructionism expands from the constructivism concept. Constructivists believe that children actively take part in creating and constructing their own knowledge, contrary to the previous views that labeled them as passive learners waiting for the teachers to transmit the information to them. Constructionism takes its theory one step further from constructivism by claiming that knowledge is constructed in social interaction (Jonassen, Peck, & Wilson, 1999; Spodark, 2005). Papert (1991) provides the simplest definition of constructionism as “learning-by-making” (P.1). He says: [c]onstructionism –the N word as opposed to the V word—shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe” (Papert, 1991, P. 1, emphasis in original). This means that knowledge is built and not supplied, and the construction of knowledge happens best when children are engaged in building something. “Constructionist thinking adds to the constructivist viewpoint. Where constructivism casts the subject as an active builder and argues against passive models of learning and development, constructionism places a critical emphasis on particular constructions of the subject which are external and shared” (Shaw, 1996, p. 177).

Accordingly, constructionism stresses the external world, environment, and the artifacts children are participating in building. Kafie and Resnick (1996) view

constructionism as both a theory of learning and a strategy of education. They express that students make new ideas when they are actively involved in making external artifacts, such as a robot, a sandcastle, and a poem. Therefore one of the tenets of constructionism is considered to be the learners' active construction of knowledge from personal experience. Kafia and Resnick (1996) see constructionism as being involved in two intertwined types of construction: the construction of the external artifacts, and the construction of knowledge (p. 1). They also stress several dimensions in which that constructionism differs from other learning theories: one, is when others define knowledge acquisition in cognitive terms, constructionists consider the importance of *affect*, and argue that learners engage more on projects that are personally meaningful to them. Second, constructionism emphasizes "*diversity*." This means both various learning styles and various representations of knowledge are acknowledged. Third, constructionism suggests a strong relation between design and learning. This is why they believe that activities that involve designing or making provide a rich basis for learning. Lastly, constructionism values the social nature of learning and the vital role of the community. "There is a growing appreciation for the role that communities play in the learning process: community members act as collaborators, coaches, audience, and co-constructor of knowledge" (Kafia and Resnick, 1996, p.6).

Research testifies a constructionist framework provides theoretical support to teachers facilitating students in the process of constructing and reconstructing their own knowledge through the use of inquiry-based learning and engagement in higher order thinking and problem-solving (Crawford, 2000, p. 918). At the same time, inquiry, critical thinking, social awareness, and reflection are the skills needed for both teachers'

and students' success. Constructionism provides a lens through which the learning of both teachers and students are analyzed. Teachers are in the process of implementing a newly learned inquiry approach for their students and at the same time are providing students with a chance to learn from hands-on activities integrated with the constructionism approach. This will give students the opportunity to move into building essential learning blocks for their own knowledge. Additionally, working in small group and being in a social context provides students with opportunities to opt for endeavoring more complex skills than what they can execute alone. Simply being able to work in a group and be in contact with their peers gives students the valuable opportunity to discuss various tasks, verbalize their thinking, and imitate or model what other students are doing.

Constructionism provided me with a lens through which to analyze the construction of knowledge and the learning of science materials for these elementary teachers and students. It is through this lens that I explored the diversity of students' learning style and reproduction of knowledge in deeper format, and investigated the social nature of learning. The constructionism lens further helped me to explore the construction of external artifacts through the meanings and significance they had for students. Also, it was of important value to realize that the social construction of the reality was an ongoing and dynamic process that was driven and maintained by social interactions (Esterberg, 2002). Next, I will discuss my other theoretical concept- Distributed Cognition Theory.

Distributed Cognition

One of the advancements in the 20th century has been in understanding cognition –the mental process that is involved in thinking, gaining knowledge, perceiving, comprehending, and remembering. The cognitive process involves the performance of complex cognitive activity that happens in the brain, like the process of remembering and thinking. Cognitive psychology started with focusing on the structure and use of knowledge in the individual mind. Thus, cognition was bounded to an individual person, thereby, explicitly leaving culture, context, and history out to avoid creating any complex understanding of cognition (Hutchins, 2000). At the time, laboratories were the research sites and individuals were the units of analysis. This setting provided a limited understanding of how cognition takes place in a real world setting (Hutchins, 1995a). As a result, the “classical” vision of cognition was built from the inside-out. “From that starting point, it followed that memory could be seen as retrieval from a stored symbolic database, that problem solving was a form of logical inferences, that the environment is a problem domain, and the body was an input device” (Hutchins, 2000, p. 10).

Distributed cognition supporters claim the distribution of cognition extends out of individual’s head to cover social interactions, material settings, and artifacts. Therefore, researchers use a broader unit of analysis to define the boundary of the cognitive system. This can include: the mind of a single individual, tools or artifacts one person is using, or a group of people working together with their tools. In other words, distributed cognition (D-Cog) attempts to understand the organization of cognitive systems from the outside-in, “beginning with the social and material setting of cognitive activity, so that culture, context, and history can be linked with the core concepts of cognition” (Hutchins, 2000,

p. 10). He argues, that cognition is about information processing, and when a real world problem is of concern, such as navigating a ship, information is processed and passed between people and artifacts (Hutchins, 2000). An essential notion of D-Cog is the idea that there might be a difference in the cognitive property of an individual and a group. This means that sometimes a task might be too complex for an individual to accomplish in a short amount of time, but a group can do it proficiently. Hutchins uses examples from his study that show under harsh circumstances the team managed to divide the task amongst individuals with specialized tools and through group interactions they were able to accomplish the task.

Tenets of Distributed Cognition. Distributed cognition has three main tenets: socially distributed cognition, embodied cognition, and culture and cognition. From one side D-Cog has the view of the social distribution of cognition, while from the other side, it has an embodied or ecological view. The first tenet is socially distributed cognition. The emerging idea is that “social organization is itself a form of cognitive architecture” (Hollan et al., 2000, p. 177). Cognitive processes are not just socially distributed; rather, they encompass both interactions between people and the structure in their environments. For instance, in Hutchin’s study, an aviation team had to calculate the position of the ship at all times (1995a). The team was made up of several crewmen who use various instruments to determine the bearing of specific landmarks. The team also had an additional two crewmen, one who would coordinate the bearings and record them while the other plots the bearing on a map. The action of this last person who plotted the bearings on the map determined the future position of the ship. However, the last plotting did not mean that person works alone; on the contrary, this team works alongside each

other and with specific computations tools to accomplish the task. Therefore, the task cannot be accomplished inside one's head; rather the cognitive operation extends to embrace "the interactions of the individuals with one another and with the tools of the space. The structure of the activities of the group is determined by a set of local computations" (Hutchins, 1995a: p. 200). To understand how knowledge and cognition are shaped and distributed in a complex setting such as a science classroom, I have selected distributed cognition as my theoretical and analytical lens to explore both students and teachers learning in the classroom. Distributed cognition had broadened the focus for the unit of analysis to include social process, i.e., in the case of my study it covered the role of other students, in addition to the function of tools and resources (Xu & Clarke, 2012). This lens helped me to focus on the way students were creating their science knowledge through the interconnected group activities they participated in and the artifacts they created (projects). It also gave me a chance to explore the basis on which teachers were aligning their inquiry-based instruction along with the artifacts they were creating (lesson plans).

The second tenet is that of embodied cognition. This means that D-Cog views the emergent mind as the result of internal and external resources. Therefore, artifacts are elements of a cognitive system. Contrary to the traditional or classical look at cognition, distributed cognition stresses the social aspects of cognition. It further allows the study of students' interaction by focusing on the unit of analysis, which is the use of information. Distributed cognition is an approach that involves the individual, the environment and artifacts. According to distributed cognition, cognition and knowledge are not confined to an individual, they occur during the individual's interactions with

others, resources, and objects and tools in their environment. Emphasis is removed from the cognitive process that happens inside the head of the individuals and placed on their interactions. This is what Hutchins (1995a) refers to as cognition “in the wild.” The focus of D-Cog is on the whole environment, which emphasizes the role of understanding the interaction between people and technologies (Hollan et al, 2000). Therefore, the goal of distributed cognition is to analyze the interaction between individuals, the objects they are using, and the environment in which the activity is taking place in order to identify how distributed units are coordinated. Xu and Clarke (2012) attempted to explore middle school students’ learning of science through D-Cog. They focused on the students’ interaction with each other and artifacts in their environment. They gathered data observing students learn about gravity by designing pendulums. Their study provided evidence that D-Cog has the capacity to advance our understating of the nature of learning in science.

The third tenet relates to culture and cognition. D-Cog believes that the study of culture and cognition are not separate because people live in complex cultural environments (Hollan et al., 2000). In various studies, Hutchins demonstrated how completing a cognitive task involved coordination not only between the people and the artifacts, but also it showed that the culture of each profession had a central role in the function of the cognitive system (Hutchins, 1995a).

Theoretical Principles. Distributed cognition developed out of ethnographic studies of airline cockpits and ship navigation by Hutchins and his colleagues to “provide a more balanced theoretical treatment of problem solving in real world situations, and to supply a new framework for cognitive science generally” (Harris, retrieved, Aug. 14,

2012). Two major theoretical principles separate D-Cog from other approaches: the boundaries of the unit of analysis, and the range of mechanisms assumed to participate in the cognitive processes (Hollan et al., 2000; Hutchins, 2000). In any research field, it is important to set the boundaries of the unit of analysis. In the traditional view of cognition, for instance, the boundaries are limited to the individual. However, D-Cog extends the boundaries of cognition beyond the individual to include the interaction between people, their resources, and artifacts. An example of the unit of analysis in Hutchins's study of the ship navigation is the bridge of the ship. As for the second principle, while the traditional view of cognition searches for cognitive events happening inside the individual, D-Cog does not limit the cognitive events to the skin or skull of an individual (Hollan et al., 2000).

When all of the agencies are participating in a goal-set cognitive process, they are in a *functional relationship*. Hollan et al. describes distributed cognition as looking “for cognitive processes, wherever they may occur, on the basis of the functional relationships of elements that participate together in the process” (2000, p. 175). An example of the functional relationship in Hutchins' study is when the navigation team collaborates while using the artifacts to find the location and the speed of the ship. A cognitive process is surrounded by the functional relationships of the agencies that participate in it. Another vital aspect of the cognitive process is *information trajectories* in the functional relationships. The patterns of these trajectories reveal the underlying cognitive architectures (Hollan et al., 2000). It is through these trajectories (transmission and transformation of information) that the course of the how information is gathered, processed, and used is described. Functional relationships and information trajectories

are part of a system that can dynamically configure itself to bring “subsystem into coordination to accomplish various functions” (Hollan et al., 2000, p. 176). Meaning, when one member of the team needed more support, it would be provided. Applying the two principles of D-Cog to human observation, three different ways that cognition is distributed will be disclosed: across the individual, across multiple individuals interacting in an organized way, and across time (this means that the product of earlier cognitive processes can affect and change the nature of a later cognitive task).

To understand the implications of distributed cognition for education, D-Cog focuses on activities in real-world settings. Thus far, most researchers have studied learning in the context of work, such as Hutchins’ study of ship navigation. Its use in classroom situations has been very minimal. However, it offers a perspective for both everyday learning and supporting innovation in the classroom. When it comes to this study, distributed cognition was used as an analytical lens to investigate students learning of science. Children’s learning is most effective when the four characteristics of learning are present. These characteristics are: active engagement, participation in groups, frequent interaction and feedback, and connection to real-world contexts (Roschelle et al., 2000). When these four essential characteristics of learning are present and supported, cognitive research shows, learning is enhanced and is most effective (Roschelle et al., 2000). D-Cog describes how cognition takes place in the real world. D-Cog is used in cases where a framework is needed to describe information processing amongst several people and artifacts. Therefore, distributed cognition provided an effective theoretical foundation for understanding student-teacher and student-student interaction and a rich framework for designing and evaluating digital artifacts. I used the descriptive

framework of distributed cognition to look at social interaction and artifact-mediated activities that occurred during small group activities. Following Xu and Clarke (2012), I attempted to reveal an image of learning in science classrooms from the D-Cog perspective. I explored students' interaction with each other and with the artifacts to learn science, and investigated the way teachers interact with each other, with the students, and with the artifacts to enhance their learning of the inquiry instruction.

The Rigor/Relevance Framework

The education system in the United States has failed to keep up with the changing nature of work, enhancement of technology, and the competitive job market despite educators' copious attempts (Daggett, 2005, 2008). In preparation for competitive university programs and careers, students need to demonstrate their ability to apply what they learn at school. Academic excellence cannot be measured by giving an individual student a score based solely on state assessments (Daggett, 2005). Daggett raises the issue that students' scores on the state assessments by itself will not help our students to fill the available jobs, thus the emphasis on test score alone needs to be changed. The reason for this, he states, is that the No Child Left Behind (NCLB) Act created a pressure for educators to get their students to the minimum proficiency levels in order to receive the required school funding. Unfortunately, this has created a misplaced emphasis in the educational environment; the emphasis has been on standardized tests and students' preparation to take those tests. Although state assessments are valuable, Daggett argues that they are not the finish line. Daggett believes "if curriculum, instruction, and relevant learning become focus, the tests will take care of themselves" (2005, p.1). This has led the creation of the International

Centre for Leadership in Education to create the Rigor/Relevance Framework to examine curriculum, instruction, and assessment.

The Rigor/Relevance Framework is based on two dimensions of higher standards and student achievement. This framework is a four- by- four matrix. The vertical axis illustrates the knowledge taxonomy developed by Bloom in 1956, with the lower left corner representing knowledge awareness and the upper left corner representing the highest level: evaluation of knowledge. The horizontal axis reflects a continuum of Application of Knowledge Model created by Daggett (2005). The lowest level of application is considered to be knowledge in one discipline (lower left corner) and with the highest level (far right) being labeled as “applying knowledge in real-world unpredictable situations” thus requiring adaptation of knowledge. The four quadrants of the framework are shown in Figure 2.2.

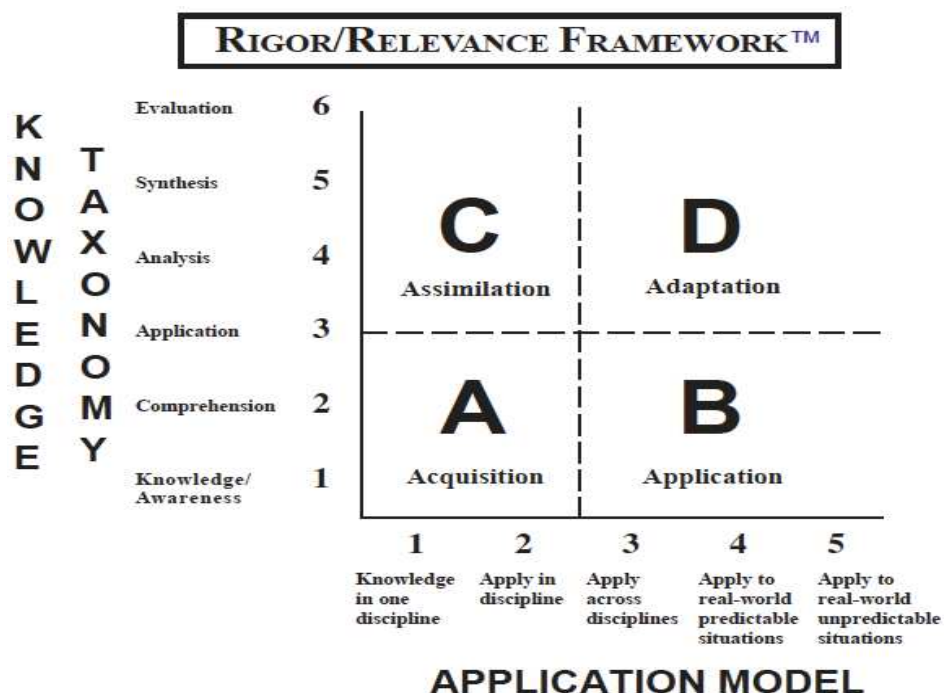


Figure 2.2. The Rigor/Relevance Framework Adapted from Daggett (2005)

Quadrant A is mere recall and remembering the knowledge with a focus on teacher work and a passive student learner. In quadrant C, knowledge is extended and refined in a way to be used routinely and automatically as the learner needs to create, think, analyze and adapt, often within a discipline as indicated in the application level. Quadrants B and D are located at the higher level of application continuum meaning that the acquired knowledge is used to solve problems, i.e., the acquired knowledge is applied to the real-world (predictable or unpredictable across disciplines) situations. Daggett's suggestion to teachers who want to add rigor and relevance to their instruction was to use this framework to reflect on how their lessons and units address each quadrant. If student work falls primarily in quadrants A and C, students may not be spending sufficient time applying their knowledge in ways that will increase their ability to think critically, solve problems, and retain what they know. He also suggests

that this framework could serve as a bridge between the community and the school to demonstrate to parents, community, and business leaders how students are developing 21st Century skills.

Summary of Theoretical Framework Review

For the purpose of this study, both constructionism and distributed cognition provided an environment in which students could learn from interactions in their small groups of inquiry and from actively participating in discussions, creating presentations, and demonstrating their understanding of the subject matter. Thus, having students in various group activities was not only a motivator, but also led to better learning (Roschelle et al., 2000). Social context provided students with opportunities to opt for more complex skills than what they could execute alone.

Distributed cognition borrows ideas from traditional research on cognition with the main difference that it states cognitive process occurs in the interaction of individuals with their environment and artifacts. Thus, this framework matches perfectly with the constructionism that believes individuals are constructing their own knowledge. The distributed cognition theory also busies itself by investigating how cognitive activities are distributed across different individual minds, across groups of people, space, time, and artifacts. It is through the interaction with artifacts and engagement in higher order thinking that constructionism provides support for teachers who are actively facilitating their students rebuilding of their own knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

As a result, enormous pressure was placed on educational organizations and educators to teach the limited skills standardized tests required; to keep up with the

necessary number of students who ought to pass the tests in order to keep the schools afloat; and to narrow their curriculum. Teachers' main distress was to raise the test scores by reverting “back to basics” in regard to the skills they covered in their classrooms. Therefore, instructions in science, art, physical education, and social sciences suffered tremendously. In addition, on those rare occasions that science instruction took place; it did not go deep enough. The damaging effects of test preparation instructions, especially when it came to low-income and minority students, have demonstrated a need for educational excellence and equity (Kohn, 1999).

Endnotes

¹Achieve is a bi-partisan, non-profit education reform organization formed in 1996 and is consisted of governors and corporate leaders who are dedicated to support standards-based education reform efforts across United States.

CHAPTER THREE: MOVING TO STUDENT-CENTERED CLASSROOMS: CHALLENGES AND BENEFITS OF IMPLEMENTING INQUIRY DESIGNS FOR DEEP LEARNING (IDDL)

Introduction

The goal of this study was to explore the challenges that teachers in one elementary (primary) school encountered when they implemented problem-based inquiry units based on the second DRAFT Next Generation Science Standards (NGSS) during a three-week science-focused summer school in 2012. This topic is important to investigate because the school in this study, similar to other underperforming schools serving socio-economically disadvantaged students, has been required for the past two decades to follow the prescribed textbook-driven curriculum. The didactic talking from the front (Hattie, 2009), lecture-based keeper of knowledge (Savery & Duffy, 1996) modes of instruction and the heavy emphasis on language arts and mathematics in these schools has provided limited opportunities for teachers to engage students in inquiry or in science. As a result, there is a critical need to understand the challenges these teachers face in successfully shifting their instructional practices and engaging students in inquiry learning.

Although science policy doctrines have promoted the use of inquiry in K-12 science for the last 24 years (American Association for the Advancement of Science, 1990, 1993), federal and state educational policies have contradictorily focused on didactic instruction, a narrow textbook-driven curriculum for reading and mathematics, and a standardized assessment system that primarily requires factual recall. Furthermore, some scholars have argued that “teaching to the test” has underemphasized the use of

21st century skills of problem-solving and critical thinking and the implementation of innovative learning approaches that align closely to the way students learn along with skills they need (Daggett, 2005; Dede, 2009; Roschelle et al., 2000; Wagner & Compton, 2012). Unfortunately, teachers in many schools, especially those serving low-income students, have been constrained by state and federal mandates to use instructional approaches that allow few opportunities for students to explore, ask questions or stray from textbook-based instruction. Additionally, the focus on teaching academic fields separately and on breadth and coverage of material rather than depth of understanding has further limited these students' opportunities to be college and career ready. It is important to understand how schools facing these constraints make the shift to meet the demands of CCSS and NGSS. Therefore, the purpose of this paper was to investigate how one elementary school, under these mandates, used a summer school extended learning time to support teachers in implementing problem-based inquiry.

The research questions that guided the study were:

- (1) What challenges do teachers face in shifting from a teacher-centered didactic approach to student-centered teacher facilitated learning?
- (2) What are the benefits of shifting from a teacher to a student-centered approach?

Changing Educational Expectations with New Standards

The Bureau of Labor and Statistics projected that 15 of the 20 fastest growing occupations in 2014 will require major training in science and mathematics.

Occupations in science, technology, engineering, and mathematics (referred to as

STEM) are “critical to our continued economic competitiveness because of their direct ties to innovation, economic growth, and productivity” (Carnevale et al., 2011). Forty-five of fifty U.S. states have adopted Common Core State Standards (CCSS, n.d.), and twenty-six states are leading partners of the National Research Council’s Next Generation Science Standards (NGSS), which require schools to focus on “deeper learning, ensuring that students are able to apply what they know” (National Academy of Sciences, n.d., Para. 3). Deep learning (Chrispeels & González, 2006; Coburn, 2003) and 21st century careers call for engagement of both teachers and students in investigation, design, creation, analysis, and evaluation (NGSS, n.d.). If students are to more deeply explore and learn concepts as well as facts, teachers must shift their practice from teacher to student-centered instruction.

In spite of the emerging recognition of the value of inquiry learning, a major implementation challenge is the need for a realignment of curriculum, instruction and assessment that matches the inquiry approach (Barron et al., 1998). The adoption of new standards that encourage inquiry will be insufficient without this alignment and assisting teachers to move to student-centered instruction. Since the 1980s, there has been a national call for change in instructional practice that help students to acquire real world competencies nurtured through complex and meaningful problems and projects (Barron & Darling-Hammond, 2010; Kohn, 1999; Levy & Murnane, 2004; National Council of Teachers of Mathematics–NCTM Report, 2009; National Research Council report, 1996; North Central Regional Educational Laboratory–NCREL policy proposal, 2003; Partnership for 21st Century Skills–p21 policy proposal, 2004). Problem-based

learning researchers and practitioners argue that frontal teaching needs to give way to teaching and learning on the side with students assuming greater roles and responsibilities for their learning (Barrows, 1985; Hmelo-Silver, 2004; Torp & Sage, 2002). Both Fullan (2013) and Hattie (2009) advocate for teachers to assume the role of the *activator* of student learning and to make room for student initiated learning.

Literature Review and Conceptual Frameworks

We start with a literature review of problem-based learning, and then explain constructionism and distributed cognition as two conceptual frameworks that provide lenses for analyzing and discussing the findings.

Problem-based Learning

As an instructional model problem-based learning (PBL) can help students acquire adaptive expertise (Bransford et al., 2006; De Corte, 2010) and engage in deep learning that will be required by the CCSS and NGSS. The “P” in PBL can refer to either project or problem-based learning. There are many similarities between the two, but there is a stronger focus on the end project in the case of project-based learning and on solving complex and ill-structured real world problems in the case of problem-based learning (Donnelly & Fitzmaurice, 2005). In this study we have used the term problem-based Inquiry Designs for Deep Learning (IDDL) (borrowing from Burke, under review). We define problem-based inquiry as an interactive process for engaging teachers and students in solving relevant real world problems that emerge from students’ inquiry in relation to the CCSS and NGSS standards. We believe one pedagogical approach that can help teachers to successfully realize a transformation to

student-centered approach is problem-based inquiry (Azer, 2009; Delisle, 1997, Gültekín, 2005; Wagner, 2010).

Benefits of Problem-based Inquiry Environment. In an inquiry classroom students (individually or in small groups) actively participate in their own learning on real problems and towards their own understanding and achievement of concrete outcomes (Barrows, 1985; Blumenfeld et al, 1991; Gültekín, 2005; Hmelo-Silver, 2004; Marx et al., 1997; Moursund, 1999; Savery & Duffy, 1996).

According to NGSS, teaching of science should be focused on a limited number of core ideas for students to learn in greater depth. Research suggests that problem-based inquiry fits this description as it engages students in research and inquiry, communication, collaboration, creativity, critical thinking, and teamwork (Ertmer & Simons, 2006; Hmelo-Silver, 2004). Students learn and retain information better and longer when they are actively engaged in their own learning in an environment that is designed to motivate them and with teachers who are activators of learning (Fullan, 2013; Hattie, 2009). Prior research suggests that problem-based inquiry makes learning “enjoyable, meaningful and permanent, and develops essential and important skills in students” (Gültekín, 2005, p. 553). When students work in teams, they play a key role in constructing their own learning through active participation and creation of their own outcomes. Studies of inquiry-based science in a large diverse Maryland district found that an inquiry approach was equally effective among low-income diverse ethnic and linguistic subgroups (Lynch, Kuipers, Pyke, & Szesze, 2005). From five middle schools 1,500 8th grade students were selected for their ethnic, linguistic, and

socioeconomic diversity to participate in a study of the effects of highly rated science curriculum unit. These students took a six-ten week unit in chemistry based on an inquiry curriculum and responded to pre and posttests on Conservation of Matter assessment and measures of motivation and engagement. The posttest results for this quasi-experiment were statistically significant for achievement, basic learning engagement, and goal orientation for inquiry students of all groups. Students in the treatment group did much better than the control group (Lynch et al., 2005). A development and research study of twenty-five 3rd and 4th grade students from six elementary schools of diverse linguistic and cultural groups engaged in problem-based learning showed similar results: the intervention inquiry curriculum enhanced the inquiry ability of all students particularly, low-achieving, low-SES, and English language speakers regardless of grade, prior achievement, gender, ethnicity (Cuevas, Lee, Hart, & Deaktor, 2005). Boaler (1998) in a similar study found that students were more able to apply their learning to new problems in a variety of settings. Nevertheless, most students, especially at the primary level, have limited opportunities for inquiry and investigative learning.

Challenges of Problem-based Inquiry Environment. Problem-based inquiry is a pedagogical model that supports learners' various learning styles and actively engages them in the learning process (Blumenfeld et al., 1991; Marx et al., 1997); at the same time, it poses challenges for teachers in reconstructing their own understanding of teaching in which students and their inquiries drive instruction (Park & Ertmer, 2007). Barell (2010) and Ertmer and Simons (2006) argue that teachers' and students' roles

need to be rethought and educational programs and goals re-envisioned based on a constructivist theory of learning.

Reviewing the literature, Tamim and Grant (2013) found five challenges teachers experienced using project-based learning: taking a constructivist approach, adopting new instructional strategies, curriculum and selection of topic, management and design of project-based learning, and the nature of collaboration (p.74). Similarly, Ertmer and Simons (2006) in their review identified three types of challenges teachers are likely to encounter when implementing problem-based learning: creating a culture of collaboration and interdependence; adjusting to changing roles; and scaffolding students learning and performance.

This study contributes to the field by empirically documenting the actual challenges elementary (1st – 5th grade) teachers confronted as they learned and worked to implement problem-based inquiry in a three-week summer school program. In particular this study contributes by exploring the added complication of teachers' simultaneously trying to integrate technology such as iPods or laptops as research, communication, and presentation tools as well as learn how to implement problem-based inquiry. The majority of teachers were at the beginning stages of both understanding and using inquiry and technology. This study is also important since the teachers were learning to shift from textbook driven instruction to engagement with NGSS to guide unit development.

Constructionism

Problem-based inquiry researchers have consistently recognized the importance of constructionism as a theory of learning that supports and aligns with an inquiry classroom (Barab et al., 2000). Many argue for a constructivist framework believing individuals actively take part in creating and constructing their own knowledge.

Constructionism builds on constructivism and takes it one step further by claiming that learners actively construct meaning and the reality of their world in and through social interaction with each other and with the teacher in an ongoing and dynamic process (Berger & Luckman, 1967; Jonassen, Peck, & Wilson, 1999; Kafia & Resnick, 1996; Spodark, 2005; Wheatley, 2007). Papert (1991) provides the simplest definition of constructionism as “learning-by-making” (p.1). He says:

[C]onstructionism –the N word as opposed to the V word—shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe (p. 1).

This definition elucidates that knowledge is built and not supplied, and the construction of knowledge happens best when individuals are engaged in building something together that is external and shared. “Consistent with Papert’s (1991) constructionist pedagogical framework, our interest is in learning environments in which learners build understandings through the collaborative construction of an artifact or shareable product” (Barab et al., 2000, p. 9). The challenge for teachers is that this theory of learning is often at odds with policy, instructional expectations and

practices, and assessment. An important theme addressed in this study is the tension teachers experience from the policy mandates for underperforming schools, and teachers' attempts to move toward student-centered constructionist learning.

Distributed Cognition

A related theory, distributed cognition (Hutchins, 1995a), draws on concepts of constructionism by recognizing the social interactions and setting in which knowledge is shared. The theory extends constructionism by more systematically exploring how cognitive activities are distributed across groups through social interaction, time, and artifacts. Distributed cognition provides a lens to understand the organization of cognitive systems from the outside in, "beginning with the social and material setting of cognitive activity, so that culture, context, and history can be linked with the core concepts of cognition" (Hutchins, 2000, p. 10). Therefore, proponents of a distributed cognition perspective use a broader unit of analysis to define the boundary of the cognitive system and the ways knowledge distribution is mediated. It recognizes that artifacts (e.g. technology, classroom seat arrangements, microscopes, textbooks, etc.) are an essential component in inquiry learning environments and need to be explored in terms of how they affect the construction and distribution of knowledge. The teachers in this study were attempting to implement problem-based inquiry within the historical context of a teacher-centered, textbook driven didactic approach to teaching and learning. This historical context provides an interesting frame for exploring the challenges they faced in making a pedagogical shift in their teaching practices.

Hutchins (2000) has argued that cognition is about information processing and “passing”— the process of information being passed between individuals and artifacts to accomplish a task or goal. When a real world problem is of concern, such as the navigation of a ship, information is processed and passed between and among individuals and the instruments (artifacts) in the variety of feedback loops used to ensure safe steerage. This theory’s attention to artifacts and their relation to real world problems/work is important for this study because of the attempt of teachers to engage students in problem-based inquiry and to integrate technology as an artifact to stimulate investigations. This interactive process is important to explore since many elementary teachers are often at a disadvantage in regard to technology and how to interface and integrate it into a problem-based learning environment (Park & Ertmer, 2007; So & Kim, 2009). In an inquiry classroom, a rich distributed learning environment exists, with peers, texts, technology, biological samples, and other artifacts providing critical mediating roles and thus increased learning opportunities, while decreasing the role of the teacher as the primary mediator of learning (Dede, 2007; Nardi, 1996). A distributed view of learning can shed light on the critical role that artifacts play in the construction of knowledge.

Methodology

Design

This study used a single exploratory case study design (Creswell, 2008; Yin, 2003) to investigate teacher implementation of problem-based inquiry in a three-week summer school session, which bounded this study. Typical of a case study, we

collected data from multiple sources (teacher interviews, observation notes from one week of professional development and three 4th and 5th grade classrooms, and a pre-post student survey on teamwork). Our goal was to create a holistic case about teachers' efforts to shift their instruction from teacher to student-centered inquiry and the challenges they faced in making this shift.

Context of the Study

The setting was an elementary school in southwestern United States serving Latino heritage students, with 93% of the students qualifying for free and reduced-price lunch and 82% classified as English language learners. The school was designated underperforming and applied for and received a three-year federal Turnaround School Improvement Grant² (SIG) in the fall of 2010. As part of the grant, the school invested heavily in technology (1-1 iPods, rolling carts of laptops, a computer lab, teacher computers and document camera, and five desktop computers for each class), with the expectation that teachers would integrate technology into their lessons. Another component of the turnaround process was to increase learning time for students, which was done through a summer school Extended Learning Time (ELT) session. The school selected a three-week summer school focused on science and literacy as their approach to ELT. The daily ELT schedule consisted of two and a half hours of instructional time. This study investigates the second year of ELT. Eighteen teachers and 560 students participated.

Professional Development: Year 1. In the first year, teachers by grade level selected NSTA's Picture Perfect and Great Exploration units in Math and Science

(GEMS, Lawrence Hall of Science) (Ansberry & Morgan, 2005, 2007). During the week of professional development prior to the summer session, teachers explored the GEMS and Picture Perfect units and selected the literature they would use. These units were implemented with relevant fiction and nonfiction texts, thus supporting both literacy and science. Teachers were not required to align their units to specific standards. Teachers were also introduced to the collaborative engagement strategies and the principles of Kagan (1994) cooperative learning.

Professional Development: Year 2. In the second year, when we conducted this study, the emphasis of the summer school changed to a standards-based inquiry approach, with teachers and administrators identifying life science standards from DRAFT NGSS (n.d.) and California science standards. The purpose of providing the professional development (PD) was to enhance teachers' knowledge and skills in conducting problem-based inquiry and time to collaboratively develop standards-aligned units. The teachers received one week of PD that consisted of learning about (a) How students learn, (b) Ways to identify students' prior knowledge, (c) A review of Kagan (1994) cooperative structures to engage all students, and (d) Inquiry Designs for Deep Learning (IDDL), which focuses on learning as a process of inquiry and problem-solving (rather than activities and projects) and provides steps for mapping a unit such as how to unpack standards, identify the "big idea," write essential questions, develop formative assessments to check progress and create a summative performance task and rubric for assessing it. As part of PD teachers had a daily collaborative time that they

used to refine their units (in grade level teams), including daily lesson plans, formative assessments and final student performance products.

Participants

For this study we interviewed eighteen teachers, 16 female and two male. The teachers were 78% Caucasian Non-White and 22% Hispanic and taught first through fifth grade during the summer of 2012 (five in first grade, four in second, three each in third, fourth and fifth grades). Sixty-one percent of the teachers were 35 or older and 39% were between 25-34 age-range. Teachers had a range of 1-28 years of teaching experience with five having taught less than five years, five with 5-8 years experience, and eight with 13-28 years experience. The majority of teachers (61%) had taught in 2-3 different schools, 16% only in this school and 22% in more than three schools (see Table 3.1).

The majority of teachers (15) had been teaching and would continue to teach in this school the following year. The remaining three teachers were from the same district but were recruited to teach at this site for the summer session. None of the teachers had prior experience in teaching inquiry or problem-based learning. However, 16 of the 18 teachers had worked together the previous summer when they were introduced to hands on instruction through the GEMS and Picture Perfect units.

Table 3.1. Demographics of Teacher Participants

Demographic category	Number of teachers
Gender	Female — 16 teachers Male — 2 teachers
Grade Level	1 st — 5 teachers 2 nd — 4 teachers 3 rd — 3 teachers 4 th — 3 teachers 5 th — 3 teachers
Ethnicity	Caucasian, non- Hispanic — 14 teachers Hispanic — 4 teachers
Age	25- 34 years — 11 teachers 35+ — 7 teachers
Years Teaching	Less than 5 — 5 teachers 5-8 years — 5 teachers 13- 28 years — 8 teachers
Number of school sites taught at during career	1 site — 3 teachers 2-3 sites — 11 teachers 3 or more sites — 4 teachers

Data Sources and Collection

Multiple data collection methods were used to develop and corroborate categories and themes.

Interviews. All eighteen teachers voluntarily agreed to participate in semi-structured individual interviews, which were audiotaped. The interviews lasted between 25-45 minutes, with a pseudonym being assigned to each interview. The interviews explored teachers' opinions on the professional development and planning as a whole, participating with colleagues as a team, and implementing the unit. Interviews also provided us with insight into how they saw the effect of the

implementation on their instructional practices and students' learning. More specifically, interviews explored participants' perceptions of the challenges and benefits in implementing the inquiry unit. Two other areas investigated participants' views of student teamwork and various ways they integrated 21st century learning structures and strategies, including technology, in the inquiry process, and how they supported students' learning (see Appendix A). An external transcription agency transcribed the interviews. The lead researcher listened to each interview to check quality and correctness of the transcription.

Classroom Observations. The purpose of the observation was to collect descriptive data that would supplement and corroborate the interview data. Given time and resource constraints, we selected two groups of teachers for observation — the six 4th and 5th grade teachers who were implementing the same standard. The observers were the first two authors and three other students. The lead author trained the team in the protocol she had developed and the team met after the first few observations to review the protocol and calibrate observations and observation techniques. The protocol (see Appendix B) focused on three main themes: (a) gaining a whole class perspective of the day's lesson and intended outcomes, (b) on the nature of teacher talk and questioning strategies to engage students, and (c) on student teamwork. In addition, the first two authors observed planning sessions of the 4th and 5th grade teachers during the PD week and two or three times during the summer school.

Document Collection. Other sources of data included teacher lesson plans, and student work samples of formative assessments and final products.

Student Pre-Post Survey on Teamwork. Researchers created a mirrored pre and post survey (referred to as either pre survey or post survey) asking 4th and 5th grade students' opinions on teamwork. Students took the survey on the first and last day of the summer school. This survey (see Appendix C) consisted of 11 Likert-type scale questions with responses ranging from “always, most of the time, sometimes, or never.” In addition there were two open-ended questions: (a) *What is the best thing about teamwork?* (b) *What is the hardest?*

Data Analysis

Data analysis adapted a constant comparative method (Glaser & Strauss, 1967). We read the interview transcripts and observation notes in random order with the goal of immersing in the data (Miles & Huberman, 1994). Data analysis adopted the research questions as the frame for coding (see Table 3.2). Data were also read with an open mind to search the variety of ways teachers surfaced the challenges and other issues such as benefits and teamwork. A similar process was followed with the observation notes (Esterberg, 2002; Saldaña, 2009).

Table 3.2. Summary of Codes, Categories Related to Two Major Themes: Students' Lack of Experience with Inquiry and Teachers' Challenge in Moving to Student-centered Instruction

Students' lack of experience with inquiry	Teachers' challenge in moving to student-centered instruction
Category: Inquiry process • Getting the concept • To be in charge of their own learning • Not knowing how to write the results from their research • Writing in their journals Category: Have low level questions • Responding to recall questions • Hard to develop their own questions Category: Collaboration • How to listen to other team members • To be on the same page with other team members • Being ready to collaborate • Getting them to talk to their teammates Category: Lack of complex tasks • Tasks not sufficiently complex to require all team members to collaborate to accomplish task	Category: Inquiry process • Keeping them engaged • Being one step ahead of students • Expecting students to come up with questions • Lack of complex instructional tasks Category: Letting go • Hard to keep it at inquiry and let students do the research • Hard not to give students the answers Category: Collaboration • Planning time with other teachers • Focus on end project rather than inquiry • Planning too much • Not knowing about appropriate web sites Category: Classroom management • The classroom is too noisy • Knowing students strengths before embarking on inquiry

In addition, the authors identified the primary components of constructionism (students' active construction of knowledge, collaboration, ability to create meaning, learning by making, and constructing a public entity) and of distributed cognition (time, culture and context, social interaction, and interaction with artifacts). They then re-read the transcripts and coded them using these categories. This iterative process helped us to categorize and group codes together to develop themes. There were high levels of agreement between researchers and differences were easily resolved. Studying the additional documents such as teachers' lesson plans and students' pre and post survey confirmed and corroborated these themes.

We also used both exploratory and confirmatory analyses for student pre and post survey. Exploratory techniques were used to measure frequencies, percentages, averages, means, minimum and maximum values. For the confirmatory techniques and in order to compare the pre and post survey data to explore the relationships between variables, we ran the paired samples t-test.

Rigor and Trustworthiness

Three strategies were used to ensure rigor and trustworthiness of this study.

Triangulation. Four sources of data were used to triangulate results and enhance rigor and trustworthiness: semi-structured interviews, classroom observations of six of the 18 classrooms, student pre-post survey on teamwork, and teacher lesson plans and student work (Esterberg, 2002). Data from the semi-structured interviews were juxtaposed to classroom observation data to check for consistency and corroborate categories and themes that emerged from the interviews. The student teamwork survey provided student perspectives on challenges of working with peers, which were then compared to teacher's perceptions from the interviews. We reviewed the student work samples to confirm or challenge observational notes regarding level of student inquiry and teachers perceptions that students struggled with the inquiry process.

Member Checks and Peer Debriefing. All teachers were given an opportunity to review and change their transcripts and none requested any change. Also, we e-mailed a draft copy of the research paper to participants. Numerous debriefing sessions were held amongst the authors to discuss the codes and emerging themes to check for consistency and to resolve differences of interpretation.

Limitations of the Study

This study has several limitations. First, this is a study of only one elementary school in a socio-economically disadvantaged neighborhood. The study of the problem-based inquiry was short in duration — three-weeks, which is a minimal amount of time to implement a complex new instructional approach. Only one set of interviews was conducted and the interviews were generally of short duration (25-45 minutes), which allowed limited time for in depth probing. However, the multiple sources of data provided convergent evidence.

Results

Research Question 1: What challenges do teachers face in shifting from a teacher-centered didactic approach to student-centered teacher facilitated learning?

Five themes emerged on the challenges teachers encountered: time; teachers' lack of experience with technology; students' lack of experience with teamwork; students' lack of experience with inquiry learning; and shifting to student-centered learning.

Theme 1: Time

Not surprisingly, time, a component of a distributed cognition perspective, emerged as a major barrier to inquiry learning with all teacher participants. On this theme teachers revealed three components: (a) time to plan inquiry units (collaboratively) and learning how to engage in inquiry; (b) time to cover the curriculum; and (c) time needed for students to fully engage in inquiry.

Time to Plan Inquiry Units (Collaboratively) and Learning How to Engage in Inquiry. Because teachers developed their own units and did not use a textbook or previously developed units related to their grade specific standard on life science, seven out of eighteen teachers commented that the planning time allotted was insufficient to explore all the possibilities of implementing a new teaching pedagogy. Teacher 41 said, “I think you just have to build in time to get those lesson plans down.” The lack of time for deeper collaboration caused frustration for teachers who were new to problem-based inquiry. Teacher 22 mentioned that “it was frustrating to find out how another teacher has implemented something in her class, and you wish you had done it the same way in your class.” Teacher 43 said “if you’re not organized and if you don’t have time for prep and setup, that’s going to impact your ... whole lesson.”

Observations of the planning time for 4th and 5th grade teachers confirmed their frustration with time as they complained that it was not enough to do all their planning (Observation notes, 06/27/2012, 07/05/2012, 07/17/2012). Similarly teachers felt there was inadequate time to learn how to engage students in inquiry. Teacher 32 was concerned about having time to further train herself in how to guide the transfer of information. She mentioned that they are so used to teaching in old-fashioned ways that they needed time to adjust to problem-based inquiry. Teacher 12 agreeing, pointed out, “[w]e need more time to learn about this [problem-based inquiry] because of our own lack of knowledge in how to use it.”

Time to Cover the Curriculum. Similar to findings of Weimer (2002), teachers in this study also reported they struggled to stay on top of what was “expected

to be taught.” They felt tension between trying to be sure the students mastered the standards and still had time to experiment and explore the essential concepts embedded in the standards. The final product was to demonstrate student mastery. Teacher 31 expressed that showing what students have learned at the end was important, but she felt there was insufficient time to cover all the material. Teacher 51 talked about the role that the students’ artifact (end product) played for him and how it became his focus “... to show what they have accomplished and covered.” Teacher 21 emphasized the necessity of having more time to cover the standards and to demonstrate student mastery. This press for coverage stems from the previous experiences of teachers being required to cover the textbook and prepare students for state tests.

Time Needed for Students to Fully Engage in Inquiry. One third of the summer school teachers considered the shortage of time to let the students explore as challenging. Teacher 33 recognized the importance of letting students be in charge of their learning. She said that students needed to “... take ownership of what they were doing and really be able to develop these high-critical thinking hypotheses... to have time for exploration, time to do it on their own; time to come up with their questions.” Teacher 15 echoed the same idea and added that if the students had more time to explore they would have made a “habit” out of it. Teacher 53 talked about how more time was needed for students to do “ more exploration... to get excited and involved. More time to let them explore and to see they can do it.” Teacher 23 emphasized the “hands-on opportunities for the students to explore;” and Teacher 42 said that more time for research would have given the students a chance to “go deeper” and make

“stronger connections” in regard to what they had learned. Teacher 21 equated more time to students being able to work more on their project and produce a better, fuller, “beefier” end product. Teacher 52 suggested having more time, she would have encouraged students to “step outside of normal classroom routines.” Observations showed that both teachers and students often felt they had to stop their work just as the team was getting into their investigations (Observation notes, 07/09/2012, 07/11/2012).

Theme 2: Teachers Lack of Experience with Technology

As previously stated, technology was a component of the grant and in the modern day classroom a key artifact. All teachers used the teacher laptop and the document camera to present videos and PowerPoint presentations. Overall, all of the teachers said they considered technology as a valuable addition/tool in their classrooms. Teacher 12 believed that iPods created a student-centered learning environment, and for her technology was “the big tease.” Teacher 32 enjoyed using various pieces of technology in her classroom. She believed that one of the initial steps in teaching students to use technology was to teach them how to take care of it. Teacher 53 tapped into students’ prior knowledge when they were watching a video or a PowerPoint by taking the time to discuss it or related subjects in their small groups.

Nevertheless, interviews and observations showed that teachers struggled with implementing technology into their daily instruction. Eight of the 18 teachers pointed to their lack of comfort in using computers and incorporating technology in their classrooms. When asked what were the challenges, Teacher 11 responded, “... the teacher! I was a challenge. Kids pick it up so fast. It was just ME being

uncomfortable with getting the [iPods] out and using it...” Teachers 12, 13, 24, 31, 43, and 41 mentioned the “lack of teacher knowledge,” “expertise,” and not being “technology savvy.” These teachers expressed that they needed training on how to fully integrate technology into their lesson plans. Teacher 15 attested if it were not for a helper (an older student helping her with the use of technology in her class) using iPods might have been “overwhelming.”

Another concern voiced by all teachers was finding appropriate kid-friendly Internet sites that provided information in an “easy-and simple” format that English language learners could understand. According to Teacher 41 they “had to create everything... We didn't have the technology research tools at the levels of the kids.” Teacher 42 also expressed the same concern saying he did not feel competent to teach students how to distinguish between “good” and “bad” information. Teacher 53 who identified herself to be super confident with computers and using them in her class also added that “if as a teacher you are not comfortable troubleshooting or problem solving with it, then it [technology] is just a burden.”

Classroom observations of 4th and 5th grade corroborate these teacher comments. For example, Teacher 43, during several observations expressed her discomfort with technology and could not guide students in using the iPods or computers for student research. Teacher 41 distributed the iPods to students but not knowing how to use them only had students watch “Brain Pop” videos. One of the 4th grade teachers was comfortable with technology and put additional resources on Edmodo for students to use. His use of technology showed that it can be a critical

artifact to promote learning, but in most classrooms made a limited contribution to distributed cognition.

The 5th grade team used the rolling carts of laptops for Internet searches and to create an iMovie trailer as the final product. Nevertheless, the research the students were allowed to do was very limited. Observations of the 5th grade classes showed that students were to search using only the key phrase “who eats whom” regarding their specific ocean food web animal (Observation notes, 07/09/12, 07/11/12). One student wanted to read more about the animal but was denied the opportunity to explore further (Observation notes, 07/10/2012). In other words, “research” consisted of very narrow teacher prescribed “textbook type reading” as opposed to research. Even in the creation of the trailer, students were given a script and photos of living things to put in the food web. From observations of the planning meetings and classrooms, teachers seemed preoccupied with the idea that mastery of the standard required every student to have the same model and thus create essentially the same iMovie trailer.

Theme 3: Students’ Lack of Experience with Teamwork

Both constructionism and distributed cognition frameworks point to the critical role of collaboration and social interaction to learning. Teachers from this school had received professional development over the last two years on Kagan (1994) cooperative learning structures as a way to build student-learning teams. Nevertheless, teachers found implementing teamwork as a challenge. Three of the five first grade teachers found it particularly challenging to implement cooperative group work. Teacher 13 said that students were not ready for problem-based inquiry developmentally and/or

academically. Teacher 53 stated, “Just because you are standing when everybody else in your team is standing doesn’t mean you are participating.” She added, “teachers need to focus on the students that are not participating and fix it, and that is a challenge”. Teacher 33 said that it is hard for teachers to break down the previous school patterns in order to create new ones such as teamwork and new groupings of students. Teacher 42 saw the past group dynamic as “where one or two kids did all the work and the others just sat there.” He tried to break that habit among his students and to teach them to work as part of a group. He bragged about his success: “students learned that they could find the answers on their own; they don’t have to depend on the teacher.” Observations showed that two 4th and two 5th grade teachers did not engage students in complex instruction so that each team member had a meaningful research task. Previous research has shown that without a complex instruction design, student teamwork is often ineffective with only one or two members doing the work (Cohen, 1994). In addition on many occasions 4th or 5th grade teachers posed a probing question to the class, as per previous cultural practices, and only a few students would raise their hand to respond to the question. Teachers did not invite teams to discuss it with the group to come up with a team response.

On the student pre-post survey on teamwork two items showed a decrease on the post-survey. These items were: “When I am in a team, I help my team to gather information and useful ideas to complete our work” (49% to 44%) and “When I am in a team, I do my fair share (65% to 53%). Neither of these changes proved significant, but may be important as they reflect that the teamwork may not have provided

sufficient complexity to engage all students (see Table 3.3). In response to the open-ended question on the student teamwork survey students were asked about what is hardest in working in a team, many students (66 of 108) wrote “teamwork” or expressed a related challenge such as “listening to others,” “talking with the group,” “explaining to the team,” “dividing up the job,” and “helping others.” Interestingly on the pre-teamwork survey only 37 (out of 96) students in response to the same question indicated that “teamwork” would be the hardest thing. This finding suggests that as students worked more in teams during the summer, they found it challenging.

Table 3.3. Summary of Students’ Pre- and Post-Survey Results Comparing the “Always” Results

Questions	Pre-survey	Post-survey
When I am in a team, I do my best to do my part of the work.	58%	60%
When I am in a team, I ask for help if we need it.	27%	60%
When I am in a team, I turn in my work on or before the due date.	36%	38%
When I am in a team, I do my fair share.	65%	53%
When I am in a team, I help my team to solve problems.	50%	53%
When I am in a team, I help my team to stay on task.	41%	46%
When I am in a team, I listen to other members' ideas with respect.	54%	61%
When one of my teammates is upset I try to find out why.	39%	45%
When I don't know something, I ask questions.	44%	51%
When I am in a team, I follow team rules (team agreements).	58%	61%
When I am in a team, I help my team to gather information and useful ideas to complete our work.	49%	44%

Theme 4: Students’ Lack of Experience with Inquiry Learning

Just as teachers found that implementing inquiry learning was challenging, they also noted it was difficult for students as well. Teacher 22 expressed a belief that students have grown accustomed to getting all their answers from teachers. She said, “I think at first they expected the teacher to tell them the answers.” Teacher 32 similarly noted:

They’re really used to just taking stuff and not really having to think about it, but spitting it back out, like filling in the bubble. Now all of a sudden you’re asking them to think for themselves and then explain their thinking. They haven’t been asked to explain their thinking before.

Others agreed that it was hard for them to teach students how to “listen,” “ask their own questions,” and “keep engaged.” “It’s hard enough just getting them to speak but to get them to answer or to ask themselves questions about their learning, that was super hard” (Teacher 14). Many teachers also felt that students were not prepared to respond to ‘how’ and ‘why’ questions.

A related issue was teachers’ perceptions that students could not express their thoughts in writing or orally. Teachers attributed this expressive weakness to students’ lack of experience in being in charge of their own learning and in developing their own questions. Teacher 21 equated this issue to students “not knowing how to communicate effectively.” Teacher 22 related this problem to the historical and contextual traditions of teachers providing students with the beginning prompt and sentences to get them started, leaving the students to fill in the blanks. The classroom observations confirmed that teachers continued to provide students with many sentence stems and often required either one or two word responses. In addition, in the 4th and 5th grade classes, students had few opportunities to conduct research or read extensively about different

organisms in the ocean food web; therefore, they had little to write about (Observation notes, 07/17/12, 07/18/12). Students also confirmed that writing was a challenge. In both the pre and post-survey when students were asked an open-ended question about what they expected to be the hardest thing about working in teams, “writing” was the most frequently mentioned item regarding academic content. Without opportunities for in depth exploration, students were more limited in their ability to create meaning—a crucial component crucial of constructionism.

Theme 5: Shifting to Student-centered Learning

The historical and habitual use of didactic teacher-led instruction put a strain on teachers in shifting to a student-centered inquiry approach. The obstacles that emerged included lack of experience with inquiry teaching and the difficulty of letting go and letting students do the work.

Lack of Experience with Inquiry Teaching. Teacher 24 regarded using inquiry as “a change in mindset or a paradigm shift” for her. She mentioned that during regular school, her classes are teacher-centered “because that’s what I was required to do. And ... a lot of schools are in the same situation where you’re doing direct instruction that’s mandated.” Therefore, switching to inquiry is “a shift in thinking for both [teacher and students] because the students were used to having information given to them.” Teacher 12 said, “I’m a linear thinker...that whole, more open, messy, collaboration part...is just not my nature.” Teacher 42 continued this line of thinking, noting that in his previous way of teaching he provided the information. He added,

I felt like I talked too much even though I didn’t want to ... I think that’s what was comfortable for myself and for the kids. Then, I just said, ‘This

is what I want you to do, and I walked around as a guiding force... You have to let go, ... I think that's what eventually happened.

Classroom observation revealed how hard it was for teachers to let go of total control of their classrooms. The 4th grade teachers struggled with the collaborative team searches and frequently found it difficult to not intervene (Observation notes, 07/10/2012, 07/17/2012).

Teacher 15 admitted that stepping away from the routines of previous teaching was important but very hard to achieve. She added, “knowing that if I can get them engaged ... and ... to come up with the questions, and let them observe ... on their own, that's the first step... I don't know if I'm there yet.” Teacher 32 connected CCSS with inquiry teaching and argued that although inquiry is “hard” to teach, it is “great” for students. Teacher 11 saw a huge difference between teacher-led instruction and inquiry, observing that didactic instruction, “does not ask a lot of questions from the students.” Admitting that she started her summer class with traditional instruction, she soon realized that what they had planned was “boring.” She and her grade level colleagues decided to make their instruction more interesting and brought in live animals for students to observe and learn from.

The Difficulty of Letting Go. The data showed that it was hard for teachers to “let go” and give students permission to explore and do their own research. Teachers mentioned this process was not easy because inquiry was not in their “comfort zone.” Teacher 23 argued the hardest thing was

... being able to let go ... as a teacher and let the students explore, because we're so used to having exactly what we want the students to know and

understand, but giving them the teacher role on their own, so that they can facilitate their own learning and ...to figure out the science concepts through their own observations and not just through mine. I had to let go a little bit, which is out of my comfort zone, at first, but that became very beneficial for their learning.

Teacher 33 also emphasized the importance of letting go as a teacher and having the students explore. She added “being able to let go and to have your students go through the inquiry process is a learning process for teachers, as well.” For teacher 14 “it was hard to make it inquiry-based without giving them too much [information]... I was scaffolding too much, ... giving them too many answers and not enough free exploration. That was hard.” Later she disclosed that “once we were doing a little more of that gradual release, they were in charge of their learning and had a lot of ownership over what they were doing.” Teacher 52, a young teacher, perceived inquiry as a bigger challenge for the veteran teachers because they had to “undo” the way they had been doing things, “let go,” and be prepared to “take risks.” Though it was difficult to let go, teachers worked on that skill because they saw the benefits of it for their students.

Tables 3.4 and Table 3.5 consolidate and summarize the findings from the observation and interview data. These tables confirm that students were engaged in constructing knowledge in collaboration with teachers and peers and that students did it through hands-on learning by making and constructing a public entity— key components of constructionism. The tables also summarize the challenges teachers faced from a distributed cognition frame as a result of limited time, culture and context and lack or unfamiliarity with key artifacts.

Table 3.4. Data Analysis through the Conceptual Framework of Constructionism

Components of Constructionism	Evidence from interviews, observations and student survey and student work
Students active construction of knowledge	Teachers referred to students' construction of knowledge throughout their interviews. Examples 4 th and 5 th grade students in teams of four observed and student work showed they constructed a food chain from four organisms. Students observed identifying "who eats whom," in the food chain. In the 5 th grade each team's food chain became a part of a class food web.
Collaboration with teacher and peers	Teacher interviews revealed both challenges and benefits of teamwork. Observation showed and student survey corroborated that it was difficult for students placed in teams of four to start working together in the first week since they had little experience and little instruction on how to work together. The post survey data indicated that working together was seen as the best thing about teamwork. Students valued it because of the opportunity to help each other. This view was a shift from pre-survey in which students said they valued teamwork so they could get help.
Ability to create meaning	Observations indicated that opportunities to create meaning were minimal because students had minimal resources, engaged in constrained research and were given simple sentence frames for responding to teacher prompts. Student pre and post survey showed that the only item that decreased in positive response was "I help my team to gather information and useful ideas to complete our work." A review of student work samples across the grades showed the work was superficial.
Learning by making	Samples of student work from every class validated that students learned by making and creating a project for their end of the summer school presentations.
Constructing a public entity	The 5 th grade iMovie trailers and the 4 th grade food web posters are examples of the <i>public entity</i> as students presented them to their parents, other students, and a team of local community researchers from a nearby university.

Table 3.5. Data Analysis through the Conceptual Framework of Distributed Cognition

Components of Distributed Cognition	Evidence from interviews, observations and student survey and student work
Time	Observations surfaced time, a crucial factor enabling greater distributed cognition, to be important when working in groups and constructing meaning. Teachers in interviews frequently cited insufficient time to collaborate in planning the unit and time for students to complete the tasks. Summer school provided a unique opportunity for both teachers and students to work in a new learning environment
Culture and context	Culture and the context of the classrooms in general and teams and small groups in particular played an essential role during the summer school. Observations indicated teamwork was constrained due to students' and teachers' unfamiliarity and lack of experience with teamwork and collaboration. Years of didactic and textbook teaching were cited as factors
Social interaction (student-student, student-teacher, artifacts in the classroom environment	Observations indicated that both teacher and students received opportunities to participate in small groups. Teachers had multiple opportunities to collaborate and interact with their grade level colleagues using various artifacts, resources, and technology to plan their unit. Teacher interviews, observation notes and student post survey revealed that students worked in heterogeneous groups with other students. Teachers interacted with whole class with small groups or with individual students. Observations of 4th and 5th grade documented that often tasks required students to work by themselves even though they were in groups. Tasks were often not sufficiently complex to require every student to have a role. One or two students were frequently observed playing a lead role with others observing.

Research Question 2: What are the benefits to shifting from a teacher to a student-centered approach?

Even when teachers faced many challenges and struggled with finding time to adequately develop and implement their units, they had no difficulty in seeing the potential and citing the benefits of problem-based inquiry. When asked how he felt about moving toward inquiry teaching, Teacher 51 exclaimed that teachers are finally “getting back to what schools should be.” He added, “As teachers it is our job to design curriculum that is interesting, engaging and fun.” Even the teacher who reported using teacher-led instruction for over thirteen years believed that “students, especially the English learners, learn better through inquiry.” She said the students need to get excited about their learning and inquiry just does that, plus it “helps them to remember.” Teachers referred to inquiry as the “best way for students”, and as “student-centered learning” because students are able to really take ownership of their learning. Teacher 11 reported that students were more engaged in the inquiry environment and at the end they showed that they had learned more. She noted, “I do think any time the kids can be engaged and excited about their own learning, they are going to take more away... They pick it up faster, take more, remember more, and retain it.” Teacher 41 stated, students

...have to be able to come up with the questions and find the solution themselves and then be able to write about it. Problem-based inquiry is, in my opinion,...200% better. You need to research. You need that information for the students and for the teacherso problem-based inquiry...is needed for the deep learning.

She continued by saying that with inquiry and students' engagement, "no child is left behind." Teacher 15 who also started the summer school with didactic instruction later reported,

I like the problem-based learning. It helps the students learn. When they're actively involved in the problem. When I was trying to give them all the information, they were kind of "okay" not quite into it, whereas once they were able to investigate on their own and come up with their own questions, observations, and understanding, that was when I really saw them come to life and take an interest in it.

Teacher 12 confessed that after years of telling her friends about her doubts as to whether teaching was her calling, she had to admit that after teaching this summer school it was "like I found my mojo again." To explain this further she acknowledged that time for change has come. "Direct instruction had its time and place, ... now we want more from kids. We want them to be creative thinkers...to be part of a global solution that's outside the box."

The Power of Teamwork. Another benefit teachers observed was that students learned how to be part of a team. During observation (07/11/2012), Teacher 43 noticed how students have "learned they could work as a team." She commented that the idea of researching independently and bringing it back to the team has been "really constructive ... it's a model that ... they're not used to." She further emphasized that "once they [students] realize that ...others are interested in what they're thinking, they can have ah-has. Then, the level of work increases dramatically in quality." Teacher 33 pointed to the value in students realizing that they needed to be in charge of their own learning. "In their groups, they had to think about everything, come up with their own questions...do their own research, and talk about their findings." Teachers

perceived that collaborative small groups gave students a chance to internalize their learning and to retain it longer. As Teacher 11 said:

I've always been big on Houghton Mifflin. It was very easy for me because it was all compartmentalized and it's just step-by-step. I do think the kids get more involved if we can help, train, or teach them to ask questions. With Houghton Mifflin, you don't ask a lot of questions and you don't have hands on and inquiry. I think when you do have hands on or when you're watching the animals or whatever, the kids start coming up with their own questions...they're going to take more away from the learning...pick it up faster... remember it.

Teacher 53 commented that through teamwork students learned how to work in a team, and how to use each other's strengths to complete the task assigned. "They learned how to divide the work... how to help each other. Because they had to rely on each other to complete the task, and all students were held accountable for knowing the answer." This was also observed in 4th grade classes where teams had to present collaboratively and each team member was required to participate (Observation notes, 07/18/2012).

The student teamwork survey also confirms the teachers' perceptions of the value of teamwork. Comparing the "always" responses of the pre and post survey, we observed that nine of the eleven questions that asked about teamwork showed a positive trend with a higher percentage of students indicating "always" on the post test. However, when we ran a paired t-test of significance, only one item proved significant at the .034 level, and it was: "When I don't know something, I ask questions." This suggests a positive impact of the summer school on students' questioning from pre ($M=1.88$, $SD=.84$) to post ($M=2.14$, $SD=.87$), $t(104)=(2.147)$, $p<.05$ (two-tailed). The

mean increase in students questioning was .26 with a 95% confidence interval ranging from -.513 to -.020. This positive trend from the pre-survey should not be over interpreted, but does suggest that students felt they could get help from their teammates. On the survey we asked students to complete the sentence: “the best thing about working in a team is...” On the pre-survey 15 students indicated working together was the best thing; 25 students gave the same response on the post-survey. Getting help from teammates remained constant on both pre and post at 35 responses.

Discussion

This study confirmed previous findings that problem-based inquiry can be effective in engaging students from low socio-economic backgrounds (Cuevas et al., 2005; Lynch et al., 2005). It also reaffirms Ertmer and Simons’ (2006) findings that teachers are faced with the challenge of creating a culture of collaboration and interdependence while at the same time adjusting to their own changing roles. In agreement with Taylor and Parsons’s (2011) review of research on student engagement, teachers in this study found their students more engaged, taking greater interest in the content, and retaining more of what they learned—outcomes that they all desired for their students. Teachers recognized it was important for them to be the activator and facilitator of student learning (Fullan, 2013; Hattie, 2009) and to engage their students in the co-construction of knowledge. This shift in practice, however, was challenging for them. This study adds to the limited literature on the challenges faced by teachers who are striving to change their instructional practices in alignment with CCSS and NGSS (Ertmer & Simons, 2006; Grant & Hill, 2006). In particular the study explored

the issues of using technology as a key artifact in the learning process and “letting go”. Both of these issues are more critical than ever given the adoption of the CCSS and the NGSS and the impending implementation of new assessments systems.

Technology Integration and the Shift to Student-Centered Classrooms

The collaborative interaction among teachers, between teachers and students, among students, and with artifacts were the highlight of the implementation of the inquiry approach attempted by teachers. Figure 3.1 captures this interactive distributive cognitive process among teachers as they planned the lesson and decided on the artifacts (tools) to use in supporting student learning and then among teachers and the students in the classroom as they used the tools in their teams.

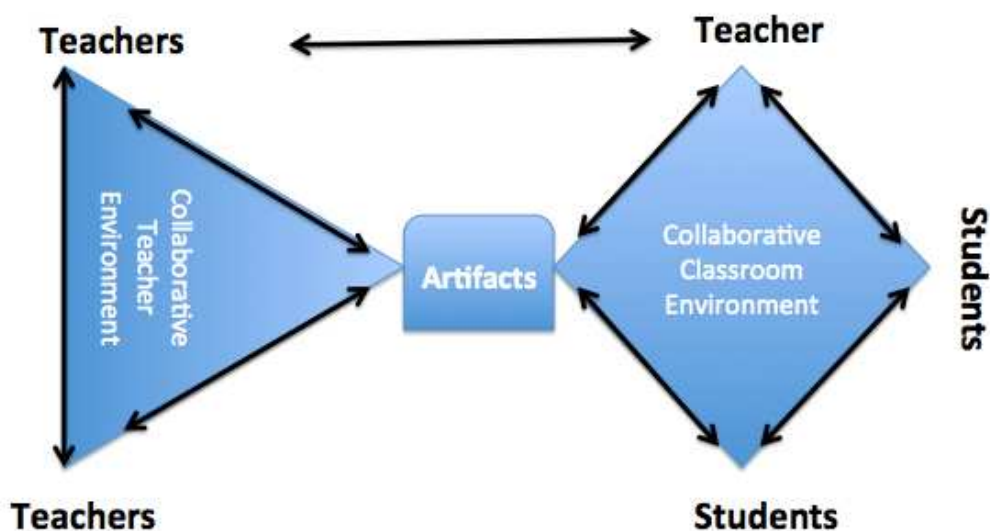


Figure 3.1. Collaborative Interactions in a Distributed Cognition Environment

A distributed cognition perspective draws attention to how learning occurs through the interaction of the group, the artifacts and the environment–time/space. In this case, the environment was an intense summer school session that allowed some, but from the teachers' perspective, insufficient time for preparing a unit of study. A critical component of problem-based inquiry is the role of artifacts in the learning process and how teachers and students interact and interface with them. Teachers identified two challenges: lack of adequate resources for both teachers and students and the lack of knowledge of how to integrate technology effectively to support learning (Edelson, Gordin, & Pea, 1999).

Teachers perceived lack of resources for inquiry learning in their classrooms, school library, and online (because of district policies restricting internet access) proved consequential and limited student opportunities for genuine research into problems. Students could research little more than what was pre-scripted by teachers. Although the teachers realized technology enhanced the benefits of problem-based inquiry, most teachers found themselves unprepared to effectively incorporate it into their lesson plans in a substantial way. Three factors seemed to be interacting, which partially explain the limited use of technology. First was teachers' own lack of comfort with technology. Although considerable technology was available at this school, its use was primarily for practice and drill using pre-packaged programs. Teachers were unaccustomed to student use of technology for research. Also there was little evidence of teachers tapping into students' ease with technology, except in the 5th grade classes when students who finished their iMovie trailer project were partnered with students

who were struggling. As previously documented, students can be significant technology coaches for teachers if they are provided with opportunities to take an instructional lead and co-construct the learning with them (Moeller & Reitzes, 2011; Patton, 2012). In this study, only one teacher involved a former student who was now in middle school to assist her in using technology.

Second, the one-week of PD and planning time before summer session was inadequate for teachers to become fully knowledgeable of the resources available on the web to support student inquiry. We agree with Taylor and Parsons (2011) who argue for rigorous instruction for students in *Information Navigation* (Brown, 2000) or “digital information literacy” (Barnes, Marateo, & Ferris, 2007; Oblinger & Oblinger, 2005; Windham, 2005). These authors also urge similar training for teachers because of their lack of digital information literacy. Learning about *Information Navigation*, teachers can model learning instead of telling students the answers, outcomes or process (Claxton, 2007). The time limitations coupled with district policies that did not allow students to freely research websites created a technology-constrained research environment.

Third, and most importantly, teachers feared “letting go”. The fear was driven by two factors: loss of control especially in the uncomfortable realm of technology and concern for failure to cover the agreed upon NGSS standard and end product. Teachers who were the ‘sage on the stage’ (King, 1993) had to realize that through letting go of their power they could provide a higher-quality learning environment for their students by drawing on students’ own knowledge. This could be accomplished through fully

using iPods and computer resources, *realia*, biological samples, and the schoolyard itself as instructional artifacts.

As Fullan (2013) has noted, bringing change has to be accompanied with effective pedagogy and change knowledge, and without it change is meaningless. The change in this case—the opportunity for students to explore in a non-textbook way an interesting problem of for instance, “who eats whom” in the food web in the ocean—was not meaningless. Both teachers and students changed and benefited from the process. However, this study highlights the need to give much more attention to the role of artifacts, ensuring they are available to teachers to fully support the learning process as part of the pedagogical training and change effort. This study also showed that teachers who accepted the challenge of implementing new approaches for engaging and actively involving students and letting go of teacher-centered instruction saw students take more responsibility for their own learning.

The Role of Collaboration in Teacher Learning

Both the distributed cognition and constructionist perspectives highlight the critical role of collaboration among teachers, and between teachers and students in the creation and subsequent implementation of the inquiry unit (Barell, 2010; Ertmer & Simons, 2006). This study showed, however, that previous instructional practices as required by state mandates (historical and current context) strongly influenced how these teachers crafted their “problem-based learning lessons” and the learning opportunities they afforded their students. Teachers came to realize that previous practices of “telling,” “informing,” and “lecturing” students did not allow students to

construct and co-construct knowledge with peers and the teacher; yet they struggled with aligning these insights with prior daily practices. Thus students had beginning but limited opportunities to engage in constructionism.

On the other hand, teachers were actively engaged in constructionism. Not only were they learning to work together as a team, but they also were experimenting with using teamwork in their classrooms. As teachers gained more experience co-constructing their lessons (Katz & Chard, 1992), they seemed more open to the advantages of students working in teams. However, classroom observations showed that teachers were not skilled in crafting lessons that enabled teams of students to engage in complex instruction where every student had a critical role in solving the problem (Cohen, 1994). As the construct of distributed cognition highlights, artifacts are critical to learning and the lack of artifacts might have played a role in teachers' failure to create more effective, complex teamwork-oriented lessons.

The summer school design provided teachers opportunities to collaborate during their daily grade level meetings, which was a new experience for these teachers. From this collaboration, teachers realized that by creating the lesson plans together they gained a better understanding of essential ingredients for successful implementation. This constructionism in action consisted of 'building knowledge structures' (Papert, 1991, p.1) for themselves and their students. Teachers engaged in the process of constructing and reconstructing their own knowledge as they debriefed their lessons and explored what was effective and what was not. Their joint planning created opportunities for engagement, critical thinking, investigation, and discovery as they

created their units, assessments, and designed the student end products—artifacts (Crawford, 2000). Similar to Roschelle, Pea, Hoadley, Gordin, and Means (2000), the findings suggested that teachers also learned science themselves as they actively participated in the construction of knowledge with colleagues. One of the tenets of constructionism, the learner's active construction of knowledge from personal experience, was confirmed when teachers reconstructed their own understanding of problem-based inquiry as letting go and letting students be more active in the learning process (Barell, 2010). The results of this study confirmed Grant's (2002) findings that teachers' planning helped them to construct new knowledge of their practice and define new roles as they shared their artifacts within and across grade levels. Also, an implicit suggestion from the results for teacher preparation and PD is the need to devote time and space for the creation of joint units to support teachers to move to a more student-centered curriculum.

Another insight was that teachers need a theoretical understanding of constructionism if they are to successfully implement problem-based inquiry; yet for these teachers constructionism is antithetical to the way they taught and in many cases are still expected to teach. Their inexperience with constructionism as an approach to teaching and learning was the basis of many of the challenges they faced (Grant & Hill, 2006; Tamim & Grant, 2013). However, the lesson planning opportunity, including task and activity creation, and grade-level formative assessments, gave teachers a chance to explore problem-based inquiry as a group and thus to expand their individual and collective understanding of constructionism. At the same time this experience led

teachers into assessing their teaching style with an evaluative eye. In this transition teachers are faced with self-managing a complex task while simultaneously helping students to do the same (Savin-Baden, 2003).

Summary

Several important conclusions can be drawn from this study. First, contrary to Brinkerhoff and Glazewski (2004) who found teachers in their study reluctant to adopt an unfamiliar teaching approach, teachers in this summer school were open to and excited about the opportunities to more fully engage students in taking responsibility for their learning. They did not reject the new approaches implied in NGSS; rather, they found them engaging and stimulating. Second, the teachers recognized the tensions between the way standardized testing has pushed them to teach and the value of more actively engaging students. Nevertheless, they faced a steep learning curve as they made this shift. Third, by better understanding the constructionist and distributed cognitive demands of problem-based inquiry, educational leaders can better support teachers in student-centered learning environments equipped with the artifacts essential for an inquiry classroom. The potential of problem-based inquiry deserves substantial attention as an effective pedagogical approach to meet the demands of NGSS, which have been adopted by many states. Inquiry approaches should also prepare student to be more successful on the new assessments developed by the consortia Smarter Balanced and Partnership for Assessment of Readiness for College and Careers (PARCC). These new assessments, which will be computer-based, will require students to analyze problems and explain their reasoning. It is our belief that teachers

equipped with the knowledge and skills to support student-centered instructions and students prepared to collaborate and learn in such environments create the right balance for increasing mastery of new standards and ensuring greater college and career readiness.

Implications for Practice

This study has three implications for teacher professional development and pre-service education. First, this study shows the power of teacher collaboration in developing NGSS aligned inquiry units. However, it is also clear that teachers must be given more time and space to do this work. One possible solution to the time conundrum would be to have teachers work in collaboration to adapt previously developed units that now need to be aligned to the new standards. Engaging in this process a few times is likely to greatly facilitate teachers' ability to create units from scratch.

Second, current and future educators would benefit from a deeper understanding of the theoretical constructs of constructionism and distributed cognition. Fully understanding the social nature of learning combined with the practical knowledge of how to build strong student teams that are able to tackle complex, messy problems (Cohen, 1994; Kagan, 1994; Slavin, 1990) would greatly facilitate the implementation of problem-based inquiry (Burke, under review). Knowledge of distributed cognition would enable teachers to think through how artifacts and students' interaction with artifacts are central to learning. The concept of artifacts is especially important as teachers learn how to more effectively integrate technology not as another "textbook"

but as a social learning tool that allows students to become knowledge builders and not just consumers (Edelson et al., 1999; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989).

Finally, teacher preparation programs and professional development must engage teachers in exploring their role and relationship to students (Barell, 2010; Ertmer & Simons, 2006). How can teachers be guided to reflect and reframe their perspective from the “sage on the stage” (King, 1993) to a facilitator and activator of learning (Fullan, 2013; Hattie, 2009)? An important first step is for teachers to examine their own questioning strategies and to shift from asking primarily factual and inferential questions, as is now typical, to asking probing and higher order questions such as how, why and analysis questions. A next step is to engage students in generating their own questions in regard to standards they are to learn, and then moving toward small-scale investigations and more complex problem solving (Burke, under review; Rothstein & Santana, 2011).

The new standards such as CCSS and NGSS, and the pedagogical approaches they require, suggest that teachers cannot continue to do business as usual. It is essential that pre-service programs and professional development be designed in ways that mirror the way teachers are to lead their classrooms.

Areas for Future Research

With the potential critical role of problem-based learning as an appropriate pedagogy for implementing CCSS and NGSS, findings from this study suggest several areas for further research. First, it would be important to document if teachers serving

more affluent communities who have been teaching under less restrictive conditions face the same challenges as teachers in this school. Second, we need to further our understanding of how to effectively scaffold problem-based inquiry for English language learners. The teachers in this study recognized that their students profited from inquiry learning, but also realized students lacked vocabulary and considerable background knowledge compared to children of higher socio-economic status. They were unsure how to engage students in using available web resources for fear they would not understand the material. A third area for further research is how to teach students to ask questions. As a result of seeing this challenge in action in this study, we have modified Inquiry Designs for Deep Learning to include PD for teachers in how to engage students in questioning. We are currently in the process of documenting the effects of this new component of IDDL. Finally, a better understanding of how to help elementary teachers effectively integrate technology into problem-based inquiry lessons is needed.

Chapter 3, in part, is currently being prepared for submission for publication of the material. Nariman, Nahid; Chrispeels, Janet. The dissertation author was the primary investigator and author of this material.

Endnotes

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²The Turnaround model selected by this school required the district to select a new administrator who in turn replaced over 2/3 of the former classroom teachers. All teachers in the district could apply for and all, including current teachers at the school, were interviewed for these positions.

CHAPTER FOUR: 21ST CENTURY LEARNING IN ACTION: UNDERSTANDING HOW STUDENT QUESTIONS ACTIVATE THINKING, LEARNING AND OWNERSHIP IN A PROBLEM-BASED INQUIRY ENVIRONMENT

Introduction and Background to the Problem

The universal didactic instructional approach to teaching, in which teachers are considered the knowledge source and their job is to transmit that knowledge to their students, constitutes the school culture of the United States (Cuban, 2008).

Technological advances and increasing globalization have been the fundamental accelerators of the calls for instructional changes (Dumont et al., 2010). United States business and educational leaders have urged transformation of educational settings to prepare students for today's challenges. This transformation from an industrial to a knowledge and digital society has created a substantial requirement for 21st century competencies, and has called attention to the quality and quantity of learning occurring in classrooms, with the concern that traditional approaches of teaching are insufficient to address skills and knowledge students now need to successfully pursue college and careers of the future (Dumont et al., 2010; Hargreaves & Shirley, 2009). As part of this transformation, Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) were developed and adopted. The CCSS and NGSS expose gaps in traditional approaches to learning (Dumont et al., 2010; Hargreaves & Shirley, 2009), which often fail to foster 21st century competencies such as critical thinking, innovation, problem solving and teamwork (Partnership for 21st Century Skills, 2009; Wagner, 2007). Hence, to successfully implement the CCSS and NGSS, schools

need to adopt a more student-centered, inquiry based pedagogy. The aim of this pedagogy is to nurture collaboration, discussion, and deliberation among students so they can develop critical thinking and problem solving skills. An integral part of the scientific method is the process of asking questions, finding data to answer those questions, and generating new questions based on the initial responses. Thus by this inquiry process teachers are instilling scientific thinking in their students. Our previous research (Nariman & Chrispeels, 2013) identified the crucial role students' questioning can play in their learning. A review of the literature, however, revealed limited research on student-generated questions. The limited (particularly with regards to how students' questions can lead to knowledge construction), and narrow (as few studies relate to the learning of science) research in this area creates the right environment for more research (Chin 2002; Chin & Brown, 2002; Rothstein & Santana, 2011).

This study draws on research on the use of questions as an instructional strategy and the Rigor/Relevance Framework (Daggett, 2005). The primary goal is to explore ways students become more engrossed in their own learning as teachers in an elementary school (K-5) implemented Inquiry Designs for Deep Learning (IDDL) and shifted their instruction from teacher-centered to student-centered by engaging students in asking questions.

The focus of this study is one elementary (K-5) school serving a large English learner and socioeconomically disadvantaged population. Because of its low achievement the school was required to follow a textbook based curriculum using didactic instruction as the primary approach. However, for three years beginning in the

summer of 2011, the staff implemented a three-week summer school program, which taught teachers about problem-based inquiry, followed by teachers' implementation of inquiry with students for three weeks. We collaborated with this school for two of the three years (2012 and 2013), collecting data on the professional development provided to teachers as well as on the three-week summer Extended Learning Time (ELT) problem-based inquiry science school. This paper discusses data collected in the last year of implementation of the summer school session (summer 2013).

The research data from the previous year was shared with administrators and teachers. As a result changes were made in the design of the program and implementation plan for the last year, 2013. For example, one of the findings from the previous year was that teachers saw the value of designing standards-based science units, but felt too pressed for time to design their own units from scratch. The design iteration for the summer session thus started planning earlier, encouraged grade level teams to select the standard they wanted to focus on (rather than every teacher focusing on a similar life science standard), and encouraged each teacher team to adapt existing units rather than creating an entirely new unit.

Another insight from the previous year's research was that teachers saw the benefits of greater student-centered instruction that drew on students' interests, but were uncertain how to increase student engagement. After discussing the results with program leaders a decision was made by the program leader to incorporate into the professional development the Inquiry Designs for Deep Learning component on how to facilitate students to generate their own questions. As a result of these changes, teachers felt their

voices were heard through the research and agreed to a second year of data collection and observations in their classrooms. Thus this study can be viewed as design-based research in which the first round of data collection influenced the design of the intervention and subsequent data collection (Collins, Joseph, & Bielaczyc, 2004).

The questions that we consider throughout this study are:

1. How do teachers stimulate inquiry and enable students to generate their own questions?
2. In what ways do student perceive they were engaged in generating their own questions?
3. In what ways did the IDDL Inquiry Prompt Process and the incorporation of the 5E model support student science inquiry?

Literature Review

On Questioning

Teachers have always used questioning in their classes; however, the U.S. education system has long emphasized that the purpose of the questions was creating responses. Traditionally the focus of teacher questions was to determine what students know. Durkin (1978-79) noted that in a typical elementary classroom nearly all of teachers' instructional time was taken up by asking questions of students. Teachers asked 80% of the questions posed in class, which were mostly factual or inferential in nature (Gall, 1984; Watson & Young, 1986). Other studies on classroom questioning confirmed these practices and have shown that teacher questioning could be considered "triadic dialogue" (Chin, 2006). Mehan (1979), and Sinclair and Coulthard (1992), for instance,

investigated what was known as the IRE discourse format in which the teacher *initiated* with the closed-ended information seeking questions, and students offered some *responses* to teacher initiation which in return the teacher *evaluated* their responses by praising the correct answers and/or correcting the incorrect responses. The IRF pattern was not teaching the students to think, rather it only taught them to know the right answers, meaning students needed to rely on their memorization of facts. Chin (2006) proposed that what was evident from this type of dialogue was that it had “restrictive effects on students’ thinking as students’ responses remain brief and teacher-framed, thus minimizing their role in the co-construction of meaning” (p. 1316).

Dillon’s study (1988) explored the lack of students’ engagement in the process of questioning that he attributed to an environment where teacher questions foil discussion and students are not participating and are not engaged in the discussion. In contrast, he suggested teachers who offered statements saw more students involvement through sharing more complex thought, getting involved in the classroom activities and participating more. Recently, Parker and Hurry (2007) suggested that for teacher questioning to be successful we need to go beyond the “recitation script” (p.311) and consider students questions or reflections as an integral part of knowledge construction in classrooms. Parker and Hurry, through their observation study that was similar to Durkin (1978-79) but 25 years later, explored whether there were any changes in the amount of instructional time by teacher asking questions and the extent to which the comprehension strategies are explicitly taught by teachers. They found direct teacher questioning still to

be the dominant strategy. Consequently, they concluded that if students are provided with opportunities to ask their own questions, they would learn and comprehend more.

Irrespective of their underlying purpose, questions help students to understand their world and make sense of it. Questions help to clarify meaning, explore, and construct necessary scaffolding in understanding the surroundings. Learning to ask the right kind of question is of critical importance, and it enables individuals to participate more actively in problem solving and decision-making (Pizzini & Shepardson, 1991). It also helps with understanding and producing insight about the problem at hand. Questions are supposed to ignite thought and motivate reflections. Thus, questioning, as a tool, helps individuals to understand their immediate environment, act upon it, and change it, while simultaneously empowering critical and cognitive thinking (Elstgeest, 1985; Maskill & Pedrosa de Jesus, 1997).

Different types of questions accomplish different goals. McKenzie (2003) distinguished between different types of questions and stated that it was to the benefit of students to recognize and identify these various types of questions and to be able to select the appropriate one at the right time. He argued that knowing differences between various types makes students more powerful thinkers. “Why” questions, he believed, involved analysis of cause-and-effect. Thus, more attention needed to be directed to the variables in these kinds of questions. There were questions that naturally lead to problem solving (the “how” questions) or to decision-making (the “which is best” questions). For instance, “how” questions that were the basis for problem solving and synthesis could be used to pull and change things around until a new, better version emerges. “Which is

best” questions required thoughtful decision-making; i.e. a reasoned choice based upon explicit (clearly stated) criteria and evidence. In the same fashion Wiggins (2007) (http://www.authenticeducation.org/ae_bigideas/article.lasso?artid=53) argued that good education comes from a lifelong habit of questioning, even during those times that we were focusing on mastering content. He emphasized that education was not about learning how to answer to questions; rather, it was about “learning how to learn.” Thus when teachers used the right questioning techniques, they ignited their class to pursue inquiry at more profound levels.

Over a century of research has shown that questioning as a best practice stimulated student thinking and learning (Flanders, 1970; Gall, 1970; Hattie, 2009; Marzano & Heflebower, 2012; Stevens, 1912), and taxonomies have been developed to describe what questions teachers should ask (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Gall, 1970). However, students are not taught or prompted to ask questions. Instead they are accustomed to teaching environments where teachers ask all the questions and a selected few students who raise their hands provide all the answers. Relatedly, Watts, Gould, and Alsop (1997), and Chin (2004) argued that student questions are diagnostic of their thinking and act as dominant thinking tools that boost meaningful learning while at the same time offer teacher clues into students’ understanding of the subject matter. However, the typical IRE pattern of questioning did not seem to promote meaningful learning because students are primarily required to parrot back the expected answer the teacher has already given the student. Some recent research on questioning showed that teachers are using questioning to scaffold students’

thinking (Chin, 2006; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). Once teachers give attention to student questions, they gained insight into their thinking and conceptual understanding (White & Gunstone, 1992; Watts, Gould, & Alsop, 1997) and into their preconceptions and misconceptions (Maskill & Pedrosa de Jesus, 1997), including their reasoning and what they desire to learn (Elstgeest, 1985). In spite of these important findings, many elementary classrooms show that teachers still pose primarily lower level factual or inferential questions, thus limiting both their own learning about students' understanding and students' opportunities to think critically. Because of the critical role of questioning to student learning, there is a need for research at the elementary level on how teaching teachers to facilitate students to generate their own questions could support student learning. In addition, little research has been conducted on how to support teachers with questions they *should* ask, how teachers implement effective questioning techniques, and how teachers are guided to improve their questioning practices (Gall, 1970, Borg, Kelly, Langer, & Gall, 1970; Sloan & Pate, 1996). We believe this study helps to fill these gaps.

The Rigor/Relevance Framework

The International Centre for Leadership in Education (Daggett, 2005) has developed the Rigor/Relevance Framework to examine curriculum, instruction, and assessment based on two dimensions of higher standards and student achievement. This framework is a four by four matrix. The vertical axis illustrates the knowledge taxonomy developed by Bloom, with the lower left corner representing knowledge awareness and the upper left corner representing the highest level: evaluation of knowledge. The

horizontal axis reflects a continuum of Application of Knowledge Model (created by W.R. Daggett). The lowest level of application is considered to be knowledge in one discipline (lower left corner) and with the highest level (far right) being labeled “applying knowledge in real-world unpredictable situations” thus requiring adaptation of knowledge (see Figure 4.1).

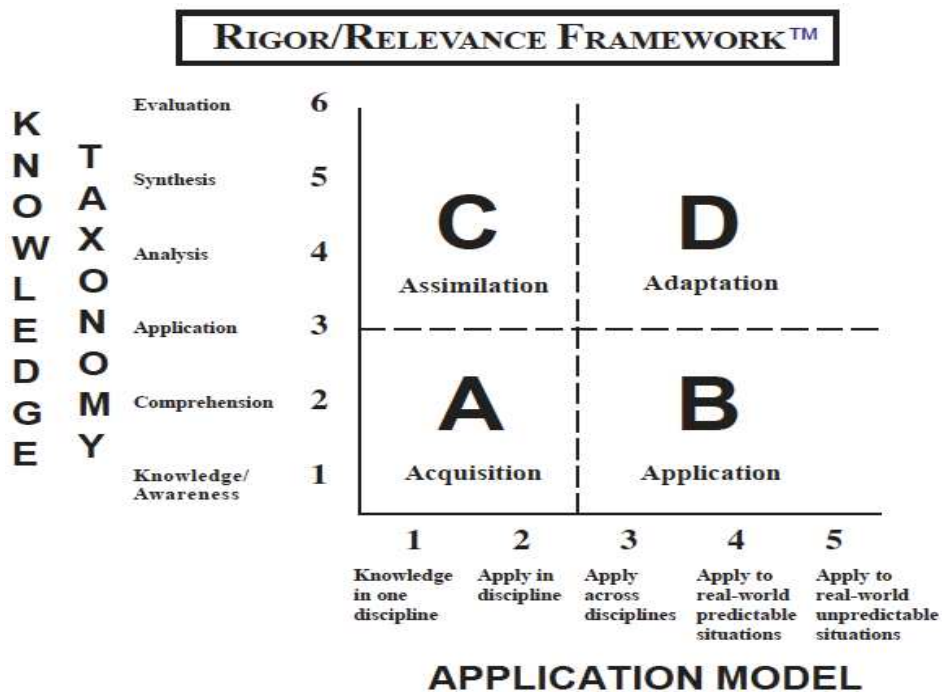


Figure 4.1. The Rigor/Relevance Framework Adapted from Daggett (2005)

Quadrant A is mere recall and remembering the knowledge with a focus on teacher work and a passive student learner. In Quadrant C, knowledge is strategic and extended in a way as the learner needs to create, think, analyze and adapt, often within a discipline as indicated in the application model. Quadrants B and D emphasize students doing the work; yet Quadrant D extends to students thinking and working. Quadrant D epitomizes student-centered learning—students’ thinking, doing, revising

and refining, reflecting (thinking) and owning the learning. Daggett advocates student-learning opportunities through instructional practices dominating Quadrants B and D. If instruction falls primarily in quadrant A and C students may not learn how to think critically, solve problems and apply new concepts. He also suggests that this framework can serve as a bridge between the community and the school to demonstrate to parents, community, and business leaders how students are developing 21st Century skills and learning how to learn. In this study, the above framework served as a tool for analyzing the observed lessons that teachers engaged students in during the summer session. It also provided a framework for exploring the level of teacher and student questions.

Methodological Approach

Design

This mixed-method design study (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) draws upon multiple data sources to construct and infer evidence of students' cognitive interactions as they engage with teachers and classmates in problem-based inquiry. The previous year's results (Nariman & Chrispeels, 2013) encouraged us to use the paradigm of design-based research for this study.

Design-based Research Intervention

Since the early 1990s, design-based method has linked theoretical research and educational practice (Brown, 1992), and its use to connect foundational research to test enhanced educational designs. In recent years, because technology has been a major intervention in education, there has been increased interest in design-based research by

the educational technology community (Bannan-Ritland 2003; Shelton & Scoresby 2011; Wang & Hannafin, 2005). The reason for this new interest is threefold: (1) design-based research is repetitive in nature, following an intervention over time, (2) it is situated in a real environment, and (3) it adopts a holistic approach toward technology-enhanced learning environment (Kamble, 2013; Wang & Hannafin, 2005). The researcher must recognize the learning setting as a dynamic one consisting of members (in this case an elementary school classroom teacher and his/her students) that have prevailing routines and specific needs (Kamble, 2013). To illustrate, introducing problem-based inquiry in a complex classroom setting as a design-based research creates demand for the researcher to be involved in all aspects of creating a new learning environment, i.e., design, development and implementation. In other words, similar to action research (Reason & Bradbury, 2007), the researcher is a participant—full or partial— in the design, implementation and subsequent data collection and analysis of the impact of the intervention. In this case, the first and second authors acted as traditional case study researchers in the previous year's data collection. After the findings were analyzed and shared with the teachers and the third author, who was the program leader for the summer school session, the research in the second year evolved into design-based research with all the authors exploring how to use the findings to enhance the professional development as well as the implementation of the problem-based inquiry in the second year.

Context of the Study

The study took place at an elementary school serving Latino heritage students, with 93% of the students qualifying for free and reduced-priced lunch and 82% classified

as English language learners. It has been designated as underperforming and was required to initiate a *Turnaround*¹ reform process. As a requirement of the turnaround process the learning time for students was increased through a summer school Extended Learning Time (ELT). To satisfy this requirement, the school selected to extend student and teacher learning over a three-year problem-based inquiry of summer school focused on science. Data were only collected in the second and third year of the program. This paper will focus on the results from the third year.

Initial Design and Yearly Redesign of Curriculum

Each year the ELT consisted of two curricular foci: science and either literacy or math. The first year focus was science and literacy; the second year science and a remedial math software program (SuccessMaker), and the third year emphasis returned to science and literacy and questioning.

The first year, teachers by grade level selected NSTA's Picture Perfect and Great Exploration in Math and Science (GEMS) Lawrence Hall of Science units (Ansberry & Morgan, 2005, 2007). Teachers were not required to align their units to specific standards. In the second year, the emphasis of the summer school was altered to be standards-based, with teachers and administrators identifying life science standards from Draft NGSS (n.d.) and California science standards. Teachers in grade level teams developed their own units, including daily lesson plans, assessments and final student performance products. We studied the challenges and benefits of implementing Inquiry Designs for Deep Learning's problem-based inquiry in Year 2 and shared the results with the teachers and administrators (Nariman & Chrispeels, 2013). These data were used to

guide planning of Year 3 ELT, including time for lesson planning during the year, provisions for more teacher and student resources, and a focus on teaching students to generate their own questions. The emphasis of the summer school continued to be standards-based for Year 3. Prior to the summer, grade level teachers explored and developed units of study that they adapted from existing units. Although teachers had some individual variations in implementing their grade level unit, they basically followed the plan they had collaboratively developed. This gave them time to prep and gather resources deemed needed to engage students. Similar to the previous two summers, teachers received a week of professional development (PD) including daily collaboration time with their grade level colleagues to plan their unit during this week and every afternoon during the summer school.

Focus of the Professional Development in Year 3. The goal of the third year of professional development was to provide two additional tools as part of the Inquiry Designs for Deep Learning protocol. The first and most important was to explicitly teach teachers how to engage students in asking their own questions. Observations from the previous year summer school confirmed what was reported in the literature review: teachers primarily asked students factual or inferential questions and students rarely asked their own questions about what they were learning (Nariman & Chrispeels, 2013).

IDDL is an instructional approach to support teachers in shifting their classrooms from teacher-to-student-centered environment and to engage students in generating their own inquiry questions in teams. In addition to designing inquiry units, teachers learned to think about their own approaches to questioning and how to engage students in

developing questions using an inquiry prompt (Burke, under review) adapted from the work of Beane and Brodhagen (2001), and Rothstein and Santana's (2011). Teaching students to generate their own questions has its roots in Burke's Inquiry Continuum. This continuum is shown in Figure 4.2.

IMPLEMENTING INQUIRY: AN INSTRUCTIONAL STRATEGY

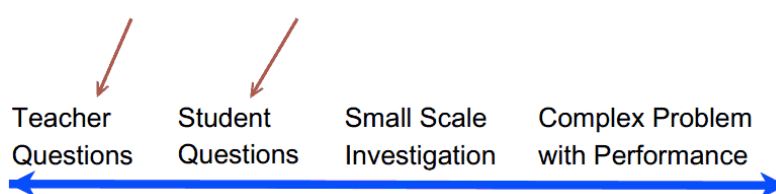


Figure 4.2. Inquiry Continuum: An Instructional Strategy Model for Implementing Inquiry (Burke, under review)

According to Burke and Chrispeels, the instructional and learning demands of CCSS and NGSS, which require students to not just know but also apply and use their knowledge, require that teachers make the challenging transition to an inquiry model. Their Inquiry Continuum advocates that teachers first become more aware of the level of questions they ask their students, and subsequently teach their students how to ask questions. According to these authors using this method facilitates teachers and students to move to higher levels of engaging work that will ensure student success in meeting the new standards.

It is essential for PD be designed in ways that mirror the way teachers are to lead their classrooms. Through two previous years of small-scale problem-based inquiry implementation, teachers learned about their changing roles, and began a gradual shift to

a more student-centered classroom. They were also moving from posing factual and inferential questions to probing more deeply with “how” and “why” analysis questions. The third year PD thus focused on helping teachers learn to engage students in generating their own questions, and to stir them toward small-scale investigations and more complex problem solving.

To facilitate the shift to student-generated questions, teachers were taught the IDDL inquiry prompt questioning process (see Figure 4.3). Rather than beginning the lesson with a question, teachers pose an inquiry prompt. The prompt, could be considered as the equivalent of a headline, however, it is based on teacher-selected standards that students are to master. For example to explore the standard on ecosystems, teachers might present the inquiry prompt, “Bee colonies collapsing across the United States.” In this process, every student has the opportunity to brainstorm and write as many individual questions as they can in a set amount of time in relation to what they want to know about this prompt. Once their list is generated, students as a class or in small groups review their questions in relation to Webb’s Depth of Knowledge (Webb, 1997), and determine which questions are factual recall questions (Level 1 questions), and which ones call for analysis, synthesis or application of knowledge. Then students negotiate in their assigned groups or as a class and decide on the top three questions that most of them want to explore. In negotiating which question(s) to select for their group work, members of the group discuss their interests and come to group agreement on questions they want to explore further. The process of leveling the questions helps students see that it is the “how” and “why” questions that are of the most interest and that

their factual questions will be answered in the process of exploring the how and why questions (Burke, under review). In addition to the one week PD on how to engage students in generating questions, teachers also received instructional coaching support from three coaches and one administrator, both on-the-spot and side-by-side to improve their questioning strategies with Karwan's IDDL Questions to Guide Inquiry Rubric (Appendix D).

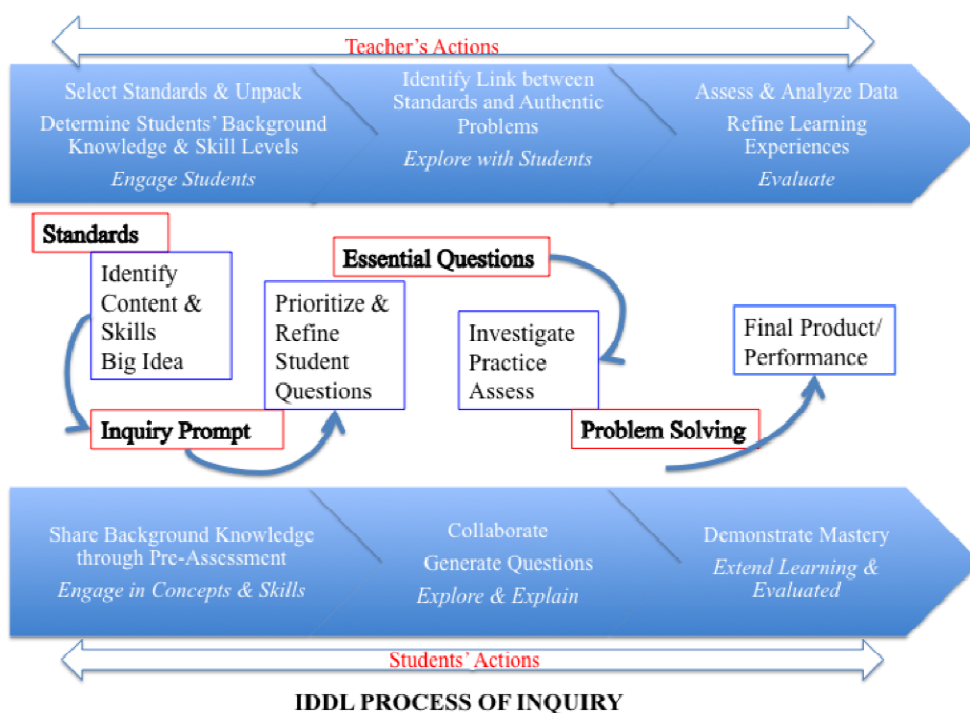


Figure 4.3. Inquiry Designs for Deep Learning Process

5E model to support inquiry. As illustrated in Figure 4.3, the 5E component of the IDDL Process was reinforced during the third year PD week. Giving attention to the 5E process was to support teachers' use of inquiry to improve students' understanding of the scientific process and literacy (Trowbridge, Bybee, & Carlson-Powell, 2004). Karplus and Their (1967) originally developed the Science Curriculum Improvement

Study (SCIS) with three phases, preliminary exploration, invention, and discovery. In the mid 1980s Biological Sciences Curriculum Study (BSCS) received a grant to produce a design for a new science and health curriculum for elementary school (Bybee et al., 2006). The BSCS consciously started with the SCIS instructional model and formulated a 5E instructional model. This model consisted of five phases: Engagement (new phase), Exploration (adapted from SCIS), Explanation (adapted from SCIS), Elaboration (adapted from SCIS), and Evaluation (new phase).

During the *Engage* phase of 5E, students' interest is stimulated. This phase provides students an opportunity to get personally involved and gives teachers a chance to pre-assess students' prior knowledge. In the *Explore* phase, students are given a chance to build their own knowledge/understanding of the topic via hands-on activities. For the *Explain* phase, students take advantage of the learned knowledge and generate explanation of the new phenomena. During the *Extend* phase students understanding is challenged and deepened through opportunities to apply what they have learned to new problems and situations. The *Evaluate* phase takes place throughout the cycle as well as during students' final demonstration of their mastery. Regular evaluation/assessment reminds both students and teacher of the amount of learning that has taken place and is thus an ongoing diagnostic process.

Study Participants. All 725 students attending this elementary school were invited to participate in the summer school program, and 560 of them registered. Based on the previous year's research results and teacher input, students were kept with the same teacher they had during the regular school year. At the end of the summer school

program all 19 summer school teachers participated in one of four focus groups. From the 19 teachers teaching in the summer program, we observed a purposeful sample of 11 teachers who satisfied the following criteria (Miles & Huberman, 1994).

1. Taught in the previous year's summer school
2. Continue to teach in this same school the following year
3. Be willing to participate in the study.

Prior to the start of summer school forty-four students, who satisfied the following criteria, were purposefully selected by the Summer School Turnaround Administrator to participate in focus group interviews. From this forty-four students only thirty-eight attended the summer school and thus participated in grade level focus group interviews consisting of 2-8 students from which 21 were girls and 17 were boys.

1. Be enrolled in the classrooms selected for observation.
2. Be from different achievement categories in their classrooms: one top student, two middle-performing students, and one low performing student based on proficiency levels in English Language Arts.
3. Reflect a balance of gender.
4. Parents' permission to participate in the study.

Data Collection

Multiple data sources, including teachers' lesson plans, samples of students' artifacts and science journals, oral presentations, classroom observations field notes, transcripts from audiotaped focus group with both students and teachers were collected. Table 4.1 demonstrates the type and sources of data used for this study.

Table 4.1. Types of Data Collected

Type of Data	Sources of Data
• Lesson Plans • Team planning minutes and documents • Classroom observations field notes • A sample of student work • Transcripts from audio-taped focus group	• Summer school communal Google doc • Teachers grade level collaboration • Classroom observations field notes • Students • 38 Students in focus groups by grade level once a week for 3 weeks
• Four transcripts from audio-taped focus groups • Teacher survey • Mirrored pre and post student science assessment • Coaching notes	• All 19 teachers • Teachers • Students • Summer school communal Google doc

Observational Data. Qualitative data included observation field notes collected twice per week from eleven pre-selected K-5 classrooms for 30 minutes per observation. The purpose of the observation was to observe first hand how teachers were implementing the Inquiry Prompt Questioning strategy and the components of the 5E lesson model over the three weeks. The lead author and a colleague developed an observation protocol and conducted all of the formal observations (see Appendix E). The third author, as the Turnaround Summer School Director, also kept coaching notes, which were incorporated into classroom observation data. The observations provided a valuable data source to triangulate with student interviews and the final teacher focus groups.

Document collection. Planning materials such as teacher weekly lesson plans, and collaboration and team planning minutes were posted each week via Google Drive and later made accessible to the researchers.

Interviews. Thirty-eight of the 44 pre-selected students and 19 teachers were interviewed for this study. Four students who were pre-selected opted not to attend summer school and were then dropped from the study. See Appendix F for student interview protocol, and Appendix G for teacher protocol.

Student interviews. The student focus group interviews were conducted with four pre-selected students from each class at the end of each week. The selected students were representative of the different achievement levels of each class—one high, two middle, and one low. Students from each grade level were interviewed usually as a group of eight or less depending on class schedules once a week for three weeks. The interview protocol involved asking the same fourteen questions of each student at the end of every week. During the interview, each student was provided with time to respond to every question. The interviews were tape recorded and later transcribed by a professional transcription service.

Teacher interviews. All of the summer school teachers also participated in focus group interviews. At the end of the summer school, the teachers were divided into four groups of four or five in order to give all teachers sufficient time to express their views. They were asked to respond to 12 focus questions. All focus groups were tape-recorded and later transcribed by a professional transcription service.

Teacher Survey. Teachers were requested to complete a survey in Google Forms immediately after the 35 hours of professional development (PD) prior to the start of summer school. Teachers responded to three open-ended questions: (a) what were the benefits of the inquiry PD, (b) how the PD supported their understanding of the way they would use questioning to help students understand, and (c) how the PD might support their understanding of why students need to generate their own questions. In addition there were 16 Likert-type questions with responses ranging from strongly agree to strongly disagree. For this study we used responses to the open-ended questions.

Student Assessment. A mirrored pre and post NGSS aligned student assessment was developed for each grade level consisting of three to four open-ended response items to assess their science knowledge related to the standard the teachers would be exploring with each grade level. The Instructional Coaches, the Summer School Turnaround Administrator, and teacher teams developed these assessments. Students took the pre-assessment in May before the end of the regular school year. During the week of PD, teachers collaboratively analyzed their students' assessment results to identify preconceptions and misconceptions they needed to remediate. This supported teacher team unit planning. The mirrored post assessment was then administered at the end of the summer school session.

Data Analysis

Data from multiple sources were examined in relation to each other and were analyzed and coded for emergent themes. This process served to triangulate the data and to help enhance the credibility of the findings (Lincoln & Guba, 1985). The Rigor and

Relevance Framework and the attributes of the 5E lesson model (engage, explore, explain, extend, and evaluate) provided an overarching context for analyzing observation notes, student's questions and teachers' lesson planning. For instance, the observation notes were explored to compare students' initial work in week one with the work completed in week three to see if it reflected a shift from acquisition of knowledge to application of knowledge. Lesson plans and observation notes were also analyzed to identify elements of the 5E model.

Data on teacher questions and student questions were coded using a taxonomy of questions (IDDL *Questions to Guide Inquiry Rubric*, see Appendix D) which presents five levels of questions including recall, skill or process questions, strategic, extended thinking and metacognitive questions. These different levels of questions helped students move from building background knowledge with factual information to active student engagement and exploration through questioning. Students' questions were coded using cognitive categories according to the type of questions asked. These cognitive categories represented students thinking, which could involve a mere recollection of facts, or higher-order cognitive processes like assuming, postulating, foreseeing, explaining, interpreting, and concluding or making decisions. Data sources were analyzed iteratively in order to examine student questions and their engagement with questions as well as shifts in the types of questions teachers asked and the level of student involvement in generating questions.

To understand the impact of the three-week summer session on students' science learning, the pre-and post assessments were reviewed in matched pairs by class. To

determine if there was an influence on student knowledge two factors were used to score the work. First, was there an increase in the use of scientific terms from pre to post. Second, did the explanations the students offered in response to the question show increased grasp of the scientific content. In addition, the final projects examined in relation to the Rigor and Relevance Framework, especially was their evidence of students application and adaptation of knowledge.

Results

To illustrate the various ways teachers and students engaged in the inquiry prompt process, we present three case vignettes from 1st, 2nd, and 3rd grade classrooms and brief summaries of the science lessons in K, 4th and 5th grades. These case studies allow us to provide more details of how the inquiry, in general, and student-generated questioning process, in particular, unfolded in the classrooms at different grade levels during the three weeks summer school session. Following presentation of the case studies, we report overarching themes common to all grade levels:

1st Grade Case Study

Two of the four 1st grade classroom teachers met the criteria to be selected for observation twice per week. Using the following standard, 1-LS1-1 “*Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs*” NGSS, n.d.), teachers focused on the topic “invertebrates and solutions to human problems.” Their inquiry prompt was that “humans mimic insects to solve problems” (1st grade teacher’s lesson plan, 06/10/2013). The problem/scenario teachers created and presented to students was:

There are many things that we see in nature that people copy and use to help them solve problems. We are going to be doing a lot of learning about insects and spiders. We will learn about their body parts and where they live (habitats). How have we used what we know about insects and spiders to design something that has improved how we (humans) live?

In addition to the problem and an inquiry prompt that 1st grade teachers crafted, they used a different focus for each week of the summer school session. In week 1, students learned about scientists and scientific methods and explored insects. In week 2, the focus was on the concept of invertebrate/vertebrate and insects. Finally, in week 3, the focus was on animals/insects and human adaptations of their structures to solve problems. Students created posters, brochures, and models of show the way people have copied insects to solve various human problems.

Week one started with the 1st grade teachers introducing what it means to be a scientist and how students would be scientists during the summer school. Wearing white lab coats, teachers modeled for students how to be curious, observant, ask questions and seek answers. They demonstrated mixing water, oil, alcohol, and food coloring. During this demonstration they continually asked the class, “What am I doing?” At the same time, to give students clues, they used metacognitive strategies of verbalizing their actions, such as “I am weighing/ measuring/ gathering tools,” and by vocalizing questions such as: (a) “I wonder what will happen if I drop the red food coloring in the water in the cup?” (b) “What is the effect of adding oil to the cup?” and (c) “I wonder why the two colors are not mixing?” Then, they invited students to ask questions. At the end of this science experiment demonstration, the teacher asked the class again, “What am I?” If students guessed the teacher to be a scientist, teacher would ask, “How did you know?”

and would request students to give clues that let them know who s/he was. Finally, the teacher showed a few slides summarizing what scientists do.

The teachers also employed the 5E learning cycle and instructional model to promote student inquiry and exploration. Table 4.2 illustrates the phases of 5E learning cycle and instructional actions teachers used to guide their instruction for every insect they introduced in their classroom.

Table 4.2. Identifying How Teachers Unfolded the 5E Process in the First Week

5E Phase	Recognizing teacher and students actions
Engage	Teacher begins with a science demonstration: weighing/measuring/gathering tools/modeling/wondering out loud/asking questions
Explore	- Students: observing - Students: hands-on activity observing insects using magnifying glass and other tools - Teacher: taking notes, probing questions, encouraging
Explain	- Students sitting on the carpet as a whole group: explain their understanding and newly found materials either to a partner or the whole class, communicating their learning - Teacher: guiding, explaining, probing questions
Extend	- Students go on a walk around the neighborhood: searching/transferring of information - Teacher: guiding, directing, probing
Evaluate	- Students: self-evaluation/peer evaluation/journal writing - Teacher: verbal feedback, written feedback in journals

After initiating the inquiry by donning lab coats and modeling the concept of a scientist comprehensible by 1st graders, teachers reiterated the inquiry prompt about how humans mimic insects to solve problems. Students (divided into groups of four)

addressed this prompt by observing several insects in their classrooms and were encouraged to write their questions in their journals. On top of each small group table there were preserved insects in jars, magnifying glasses, science journals, and pens. While students were left to observe the insects using magnifying glasses, the teachers walked around, asked students probing questions and noted statements the students were making. During their observation, teachers introduced and repeated scientific vocabulary words. For instance, the teacher would ask a small group what they were doing. They would say, “We’re looking at the insect in the jar”. The teacher would respond, “So, you are observing the insect in the jar.” The teachers’ notes were later transferred to poster board and displayed in front of the class where students gathered for their whole group activity. Teachers wrote students’ statements on the poster board with the student name beside them to give them recognition. Then, they used “I wonder...” sentences (e.g., I wonder if ants bite?), and finally the teacher added more open-ended questions, such as, “Why do ants bite?”

Later, the teachers took students on a neighborhood walk to explore how humans have used their knowledge of bugs and animals to solve their own problems. Upon their return, teachers initiated their classroom session with a PowerPoint that demonstrated how humans copy structures and attributes of animals in clothing, helmets, airplanes, hook-and-loop fasteners, and bridges (Teachers’ weekly planning data, 06/26/2013). Thus, the first four phases of the 5E served as helpers to the inquiry prompt to ignite students’ curiosity and motivation to learn more about both insects and humans. Teachers evaluated students’ learning through journal writing and drawing in order to

check for student understanding and adjust instructional planning in Week 2. Teachers collaboratively examined their journals in their meeting (Teachers' weekly planning data, 06/26/2013).

Week two started with a focus on differences between vertebrates and invertebrates. Teachers wanted to make sure that students understood the distinction between what makes people and insects different, and at the same time, teachers tried to show the connections between objects like helmets, firefighters' suits, wetsuits, et cetera, to structures in insect or mammals body parts to demonstrate how humans have copied insects and other animals. Teachers needed to ensure students knew that insects and spiders have structures on the outside to protect them, and humans copy these structures to protect their bodies (personal communication with Teacher 11, 12/03/2013). The teachers started the week with x-ray images of human and insect bodies as their engagement strategy, and continued throughout the week with discussions, observations, and videos. Midweek, they developed a thinking map by drawing a big spider in the middle of a chart and activated their students' prior knowledge with an "I know..." activity, the first part of forming a Knowledge-Wonder-Learn (KWL) chart. The KWL process is a graphic organizer designed by Ogle (1986) to foster learning by engaging students' curiosity, knowledge and interest by activating background knowledge. The KWL process clarifies what students know (K), what they want to learn(W), and what they have learned (L) (Field Notes, 07/05/2013). Some of the students' misconceptions about insect body parts that emerged in this process were that ladybugs can call for help, and that bees bite. Observation notes revealed that teachers noted these misconceptions

and raised them later in their probing questions to groups. The phases of 5E were repeated three more times in this week to discuss and learn about ants, praying mantises, and grasshoppers. The *Evaluate* phase of 5E occurred across all the other 4 phases as teacher and students assessed and celebrated the amount of learning that was taking place in each phase (Field Notes, 07/02/2013). In addition, students evaluated their own learning by writing and drawing in their journals, and teachers checked for understanding from their entries. Teachers used student journals as a feedback loop to students, sharing student exemplars as anchors so other students could explain and extend their thinking and learning (Coaching Notes, 07/02/2013). In Week 3 students demonstrated their acquired knowledge by creating posters, brochures, and models of how people have copied insects to solve a human problem.

2nd Grade Case Study

There were four 2nd grade classes in the summer school and again two of them were purposefully selected for observations. Second grade teachers used four standards, 2-LS-2-1 “*Plan and conduct an investigation to determine if plants need sunlight and water to grow;*” 2-LS-2-2 “*Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants;*” 2-LS4-1 “*Make observations of plants and animals to compare the diversity of life in different habitats;*” and 2-PS1-3 “*Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object*” (NGSS, n.d.).

Their inquiry prompt was “animals wants vs. animals needs, ” and the problem/scenario the teachers crafted was: “[T]here are less pollination insects (bees,

butterflies, beetles, etc.). This has created a problem for plants since many are dependent on insects for pollination. Design and create a model by mimicking those insects to pollinate plants” (Teachers’ Summer School Calendar, 07/15/2013). Each week had its own focus. In Week 1, the students identified the purpose of the flower and its parts. In Week 2 students explored materials and properties that worked best for picking up and dropping off pollen. Week 3 students used their knowledge of pollination to help them design a hand pollinator to pollinate a real flower. At the same time students created a StoryKit on their iPods to explain what would happen if pollinators were eliminated. The culminating activity was to share and present to parents and other classmates their individual stories and inventions.

The first day began with class and team building exercises and partner work, and ended with a nature walk. During the class building activity, teachers asked students to jot down in their science journals what they enjoyed/liked about science and to share their notes with a few other students with a Rally Robin inside/outside circle Kagan cooperative learning structure (Kagan & Kagan, 2008). Group/team building/bonding followed a similar structure with students reflecting individually in writing for one minute as many science-related vocabulary words as they knew, and then sharing it through Round Robin Kagan cooperative learning structure with other teammates. Then, working with a partner, students sorted living and non-living images into two groups using a blank paper to create a T-chart. During this activity, teachers asked probing questions, such as, “What makes something living?” and “How do you know if something is living?” Throughout the remainder of the first week, teachers unfolded the

5E phases as well as the steps for generating questions. The purpose of these activities was for students to identify flower parts and their purposes. During the *Engage* phase students watched a video clips of plants with a pollinator (bee). Following the inquiry prompt questioning process, students were then given a few minutes to write as many questions as they had about bees and pollination. The teacher charted every student's questions exactly as stated. In small groups of four, students discussed their questions, which had been recorded on the anchor charts. During this discussion time, the teachers walked around and asked probing questions to gain an idea of students' prior knowledge (e.g., plants need sunlight and water to grow, plants come from seeds, and they have parts), students' misconceptions (e.g., plants are non-living, flowers just make the plant pretty, and flowers protect plants), and questions regarding plants and pollination (e.g., why do plants need animals to reproduce?). In the *Explore* phase, students examined various plants in their small groups. First, students observed teachers modeling how to dissect a flower, naming the various parts of the female and male plants and describing the function of the plant parts. Students then dissected their own flower. Also, students were given specimen of various pollinators in jars to observe. During this phase, the teacher monitored the classroom and asked questions to make sure that students were paying attention to different parts of the flower and the details of the pollinators in jars. For instance, teachers would ask students whether they knew what the function of a specific part of the plant was, or whether they saw any patterns across different plants. For the *Explain* phase students drew pictures of their flowers and plants, labeled various parts, and wrote an explanation about each part's purpose. Later, when students circled

on the carpet, the teacher asked them to work individually responding to a few questions. For instance, students were asked to explain their thinking/findings on why they thought the plants had flowers and what they thought would happen if plants didn't have flowers, and what did they think was the role of the bees in the video they saw earlier. After a few minutes, the teacher asked them to share and charted students' responses on anchor charts. Later, teachers attempted to correct students' misconceptions by asking probing questions such as, "What do living things do? Do they grow? Breathe? Drink? Need water? Do living things reproduce?" Of course, each teacher's questions were dependent on student responses in their respective classes. The *Extend* phase included asking students to use their newly acquired knowledge to again draw a flower and label its parts. Second grade teachers considered the *Evaluate* phase to be embedded in each phase and thus reflected accomplishment in each phase.

Week Two started with plants and pollination. Through the phases of 5E model, students learned about other plants, flowers, their parts (stigma, anther, ovule), and their comparisons. This was done through watching scientific videos, hands-on experimenting and dissecting, reading books, and searching the Internet. Teachers identified and distinguished between different tasks scientists do and steps they follow (researching, exploring, data gathering, experimenting, observing, and writing the results). Later in the week, they repeated the inquiry prompt questioning process regarding pollinators. Starting with the images of pollinators, teachers asked students to jot down what they noticed, what they observed and what were they wondering about. Then, they showed a video of pollinators and asked students to write as many questions as they could in the

next few minutes. Students shared their questions in their small groups. Teachers showed students how to highlight their “how” and “why” questions in order to generate more questions (Coaching Notes, 07/08/2013). Next, in small groups, students prioritized the top three questions for their group. Groups shared their questions and the teacher charted those questions for all to see.

Another activity students did during this week was to observe various specimen insects in jars and fill out observation sheets the teacher had provided. They were instructed to pay close attention to the insects’ parts, size, etc. to be able to use them in the StoryKit to talk about pollinators. Other experiments involved testing various materials in class to determine which ones worked best for picking up pollen type ingredients (e.g., baking powder).

Week Three was primarily focused on putting students’ knowledge of pollination to use by having them design a hand-pollination device. Students were also writing about pollination in StoryKit on their iPods to explain what would happen if pollinators were eliminated to share and present to parents and other classmates at the end of the summer school.

Teachers demonstrated and identified scientific processes as they engaged in this inquiry work. In their inquiry lessons, teachers selected an activator role for themselves. From this role, they provided guidance by indirectly using various questioning strategies. They provided their students with various real-world scenarios about plants, flowers, bees/insects, and pollinators, and supported students with probing questions from the IDDL Questions to Guide Inquiry Rubric so students could formulate their own solutions.

During this process they monitored students' progress towards reflecting on their learning goals, helped them with group and teamwork dynamics, responded to their questions by probing deeper with questions, and assessed students on their final presentations so students could extend their thinking and that of their peers.

3rd Grade Case Study

Of the four 3rd grade classes offered during this ELT, two classes met the observation criteria and were observed twice per week. The NGSS standard they selected was interdependent relationships in ecosystems. More specifically, they selected NGSS standards 3LS4-4, stating: *"Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change,"* and 3-5-ETS1-2, which says: *"Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem"* (NGSS, June 2013). Their inquiry prompt was, "An oil spill has multiple effects in an Ecosystem" (Field Notes, 07/02/2013), which linked closely to the standards they wanted their students to master. The problem/scenario teachers created and presented to students was introducing a man-made disaster, such as an oil spill, and encouraging students to find solutions and be able to defend their choice. The engaging problem scenario and the inquiry prompt created a platform for teachers to introduce the science content standards.

Similar to the 1st grade, 3rd grade teachers collaboratively planned and scaffolded three overarching concepts students were to learn during the three weeks. The focus of the first week was how animals adapt over time to help them survive in their habitats.

The second week's focus was the introduction of a man-made disaster. Finally, the third week's focus was on finding solutions to the problem and presenting it by creating a poster where steps taken to solve the oil spill problem were clearly identified.

Throughout the whole summer school, 3rd grade teachers used and emphasized various students engagement strategies, such as summarizing, note taking, partner talk with face or shoulder partners, and active listening strategies including having students orally paraphrase back ideas shared by other students (e.g., "I heard you say..."). In fact, their first opening class building activity was for students sitting across from each other to use a Rally Robin timed pair share Paraphrase Passport Kagan cooperative learning structure (Kagan & Kagan, 2008). In this case, the first student on cue would say, "Hello! My name is _____ and my favorite animal is _____." The second student would respond, "I heard you say_____."

To introduce the interdependent relationships in ecosystems and to show how animals adapt to changing environments, teachers started the first week of the summer school with the *Engage* phase of the 5E model. Teachers gave each pair of students a set of six images of make believe/bizarre animals and asked students to sort them into two different environments: desert and forest. This activity was to stimulate students thinking about categorization of animals and also to identify their misconceptions. Students participated in sorting without any direct instruction. While students were discussing where to put each animal, teachers listened and took notes on which students' statements or actions revealed preconceptions and misconceptions. This activity was followed by a

classroom discussion on where and how each animal was placed according to its physical characteristic.

To move to the *Explore* phase, teachers offered three stations where they displayed three sea creature specimens with unique structures or characteristics that have evolved in ways that allow them to fill a certain niche in the ocean. Students in small groups of four noted and discussed what they observed. Then, individually students made prediction and wrote them in their science journal using the following sentence stems:

I predict this sea creature lives _____.

I predict this sea creature moves _____.

I predict this sea creature eats _____.

I predict this sea creatures protects itself by _____.

Some adaptations I observe on this sea creature are _____ (Teachers' lesson plans, 6/26/2013).

To give students an opportunity to demonstrate what they had learned, during the *Explain* phase teachers gave students a new sea creature and had them make predictions based on their prior learning. They individually took notes in their science journal, using the same sentence frames to record their predictions. As students shared their predication, the teachers asked probing questions to the rest of class such as, "What do you think about what [student] said? "Do you agree? Disagree? Does anyone have the same idea but a different way to explain it?" (Teachers' lesson plans, 6/26/2013). Later, teachers provided the whole class with a mini lesson on various adaptations of sea

creatures based upon where they live, how they move, what they eat, and how they protect themselves. To apply their knowledge to a new situation and to extend their learning, for the *Extend* phase, teachers asked students to create and design a fish with specific characteristics that will survive in a particular ocean environment given them by the teacher such as the ocean surface, the twilight zone, and the deep ocean zone. According to the teachers, the Evaluate phase was incorporated and embedded the other four phases of the 5E model.

The second week started with teachers providing opportunities for students to make a small ecosystem of ocean animals and learn how animals are interdependent on each other (e.g., seal, squid, fish, seaweed, phytoplankton) (Teachers' lesson plan, 06/26/2013). Teachers also initiated the idea that "humans change ecosystem." For students to grasp this issue, they took a walk around the school campus to observe and connect with what was happening in their living space/ecosystem. After the walk, with teachers' probing questions, students shared their observations and identified trash as a factor affecting their school. Teachers guided them in brainstorming ideas about preventing and alleviating pollution at their school site. During this week, students practiced and used the questioning strategy in multiple circumstances. For instance, when Teacher 33 had a visitor (her own sister) she invited her class to get to know the guest in their classroom through asking questions, and noticed their questions were mainly closed questions requiring only one-word responses or they were yes/no questions. To extend students' thinking, she used the presence of her guest to guide students towards asking more open-ended questions. For instance, when a student asked

the guest about her favorite color, or how old she was, the teacher probed them by asking how this information would help them in learning about their guest or introducing her to other students. Soon the students were asking the guest about what brought her to their school, and how did she compare it to her work place.

On many occasions students made their observations and then generated their own questions. For instance, on their walk around the campus, they took their science journals along and noted their observations. Upon their return to the classroom, students used their iPods to verbally record their questions individually. Next, they shared their questions with a partner and engaged in identifying the type of questions as either closed or open-ended. They also identified which questions would help them answer the inquiry prompt, which were later recorded on a class poster. Later, in a class discussion and sharing session, the teachers recorded a class-generated question poster. This tangible activity of exploring their own immediate environment facilitated students' ability to generate questions and provided students with a concrete observable example as well as time to gain a clear grasp of human caused environmental pollution and possible solutions. The teacher's goal was to assist students to transfer these environmental insights to the more abstract problem of the oil spill in the ocean.

Observation notes (July 15-18, 2014) showed that Week Three was dedicated to hands-on experimenting. Students in small groups of four created a simple artificial aquatic ecosystem with clear bucket and tap water and then "polluted" it by adding vegetable oil to it. They took time to explore the options of using nylon, yarn, cotton balls, and paper tissue to remove the oil from the artificial ecosystem. During this

activity, the 3rd grade teachers expressed to the researcher their own doubts as to whether their approach of also incorporating the Engineering Design Process from NGSS document (2012) would work. The Engineering Design Process was introduced as a series of steps engineers use to guide them as they solve problems, as shown in Figure 4.4, which was posted on every third grade classroom wall (07/15/2013). The process consists of five steps: *Ask* involves identifying the problem, and/or and brainstorm ideas; *Imagine* includes brainstorming possible solutions; *Plan* comprises drawing diagrams and/or making lists of materials needed for the solution; *Create* involves following the plan and testing it; and *Improve* involves talking about what worked and what did not work.

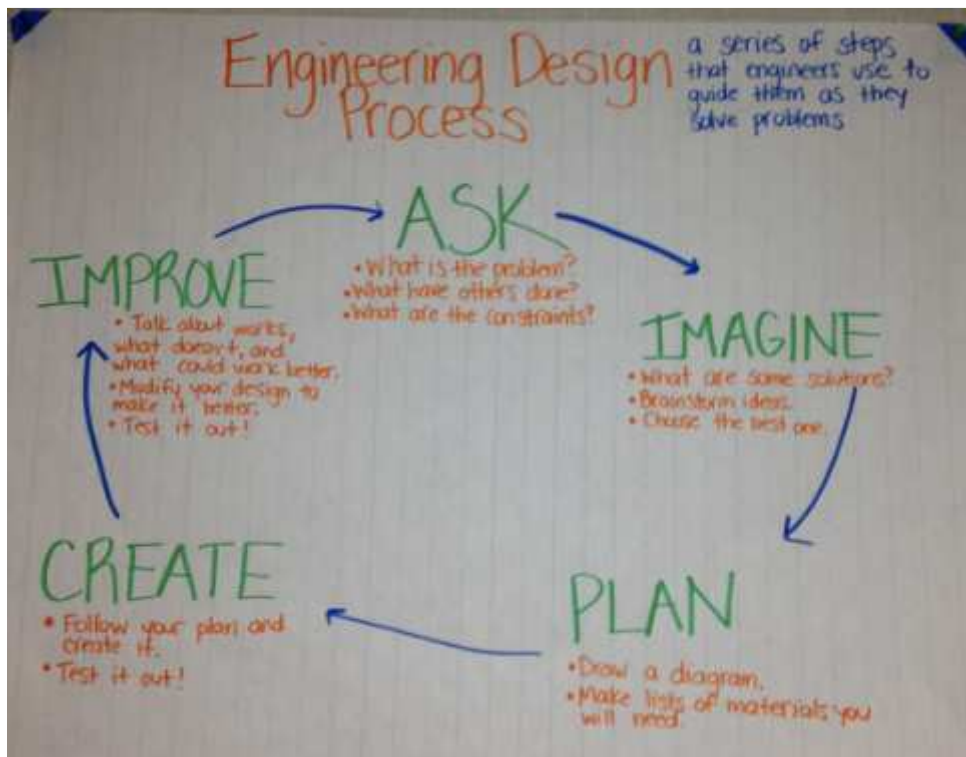


Figure 4.4. The Engineering Design Process

By going through the process of cleaning up their own micro oil spill, students imagined, predicted outcomes and then tried solutions that involved using the materials provided. They drew up a plan, made a list of the materials they needed, and then followed and tested the plan. After each trial, students discussed what worked and what did not work in their groups and then tried other solutions. The Teacher 32's listened in on their discussion as *Team Red* discussed the life situation for ocean animals faced with oil spills. Their worry was, "How do these animals protect themselves from getting covered in oil? How do they find any food? Can they move away to another place?" Teacher 32 continued listening to this team and redirected the team through questioning to focus on finding the best solution to the oil spill (Observation notes 07/11/2013). Finally, the students realized that as long as the oil is there, it affects everything else they are talking about. Therefore, they agreed the best way and the first step would be to clean the oil from the water.

Originally, teachers thought that students were struggling and were having a hard time learning the Engineering Design Process (Personal communication to observer 7/15/2013). However, when students made the connections from this process and the real-world problems they were working on (namely, their experimental aquatic ecosystem at first, and later on thinking about the recent oil spill disaster), teachers felt the process had made their students stronger and more successful (Observation notes, 07/15/2013). Teachers noticed how students had connected what they were learning about problem-solving to their oil spill project and "put their heads together like

engineers” and tried to solve the problem by finding the best solutions (Teacher 32 reflections with observer 07/17/2013).

Common Strategies and Methods to Promote Inquiry Across Grade Levels

Similar to the three case studies, we observed the usage of the 5E model and implementation of the inquiry prompt also in the Kindergarten and 4th and 5th grade. For instance, in the 4th grade classrooms they focused on energy and completed projects related to energy poverty. The 4th grade teachers led their students through simple experimentation of electricity and helped them learn about various ways that electricity could be produced. Teachers demonstrated and identified scientific processes while exploring the nature of electricity. Teachers provided their students with various real-world scenarios about energy poverty and people in need of electricity, and moved to the side to provide students with only as much help as needed in formulating their own solutions.

There was only one 5th grade class participating in the inquiry science summer school program. This class tackled the 5-ESS3-1, earth and human activity standard. This standard specifies “*Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment*” (NGSS, n.d.). The inquiry focus for this particular 5th grade was: “The United States is running out of resources.” After exploring earth resources and what was renewable and what was nonrenewable, their focus came to investigating “What is polluting the water and causing the fish to die?” (Teachers’ Collaboration notes, 07/05/2013).

The NGSS standard kindergarten teachers selected were K-LS1-1, stating: *“Use observations to describe patterns of what plants and animals (including humans) need to survive,”* and K-ESS3-1, which says: *“Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live”* (NGSS, n.d.). Their inquiry prompt was, “Animals’ wants vs. needs” (Teachers’ Collaborative notes, 07/01/2013). The problem/scenario the teachers created and presented to their students was: “Zookeepers are doing research about animal habitats so they can take better care of their animals. We have been selected as junior zookeepers to recreate the habitats so that they can do a better job making sure that all the animals get their needs” (Teachers’ Collaborative notes, 06/28/2013).

In addition, teachers from across all grade levels facilitated the collaborative small-group problem solving activities. The observations documented that the problems students were trying to solve in their summer school classes were open-ended and intentionally vague, providing students with opportunities to engage in deep inquiry: ask questions, explore, learn new information, and find their own solutions. Here we report on three common themes that further address the research questions: (1) The ways teachers stimulate inquiry and enable students to generate their own questions; (2) The Ways students perceive they were engaged in generating questions and (3) The ways the IDDL Inquiry Prompt process and 5E Model support science inquiry.

Theme 1: The Ways Teachers Stimulated Inquiry and Enabled Students to Generate Their Own Questions. The week prior to the start of the summer school teachers received one week of professional development teaching them how to engage in

problem-based inquiry and generate questions. On the post-PD survey teachers indicated that they now recognized the benefits of inquiry and questioning. In regard to inquiry, teachers overwhelmingly described its potential benefits for students. One teacher said, “I have been challenged to turn my teacher-centered practices into more student centered teaching. Additionally, I have been provided with many instructional tools to make it happen.” Another teacher commented,

The benefits of the PD allowed me to think about what the students will need to be successful in the process of inquiry. We planned from the student's perspective and worked to make sure that everything that we did directed the learning back to the students...This makes us (the teachers) facilitators of learning and the students to become more engaged and also take more ownership in what they are learning and how they are learning it.

Two specifically mentioned, “I have a better understanding of how to help students learn through problem based inquiry” and “I know how beneficial problem-based inquiry is for students. I am trying to shape my lessons so that students can "solve" a problem that includes many different lessons rather than teach unrelated standards.”

Additionally after their week of professional development all teachers reported on the survey that they now recognized how important it was to teach students to generate their own questions. For example, one teacher said, “It reinforced the fact that teachers need to use questioning to help students get to a deeper level of understanding” Another wrote, “I am beginning to get a good grasp of the probing questioning that will help kids with their learning. I can see how they benefit from exploring the answers to their questions instead of the teachers”. A third teacher added,

The PD supported my understanding of the ways teachers use questioning by giving me insight into the ways that other teachers have used questioning to ignite their classes in the exploration of new topics. I also learned that questions need to be planned and thought out so that teachers are ready to direct the learning in the direction of the learning target. Ultimately, it comes down to teachers knowing what the students should learn (the standards) so that he or she can backward plan to ensure that the questions that are asked direct the students' learning in the right direction.

Another teacher summarized the perspective of many saying, "I'm used to asking all the questions, but the PD demonstrated the shift of how the student should be doing the questioning. Through asking questions, it allows students to take ownership of questions and spark exploration that will further help them internalize the concepts."

The observation data support that all teachers began the ELT with an inquiry prompt to engage and stimulate student inquiry (e.g. the third grade prompt was that "an oil spill has multiple effects on an ecosystem"). As shown in the case descriptions, teachers in the lower primary grades guided questioning as a whole class process. In contrast teachers in the 4th - 5th grade classes used small groups to have students generate and record their questions on a poster/paper. In the lower primary classes, teachers guided students to think about how to change statements into questions using an "I wonder strategy" and by explicit modeling of questions themselves. In the upper grades students in their small groups read their questions and changed any statements into questions. Students then identified if their questions were closed or open-ended. Later, as a group (4th and 5th grades), students selected a question to explore that encapsulated the group's interest and reflected an open-ended problem. The group then started to work on finding solutions to their question. In grades K-3, teachers assisted students to identify their questions through guided instruction. This included taking them through

the KWL process, leading them along the steps for generating their own questions. In addition, teachers helped students understand the difference between closed and open-ended questions (e.g., “Why do grasshoppers hop?” to a higher order question that involved problem solving, “What can farmers do to save their crops from a swarm of grasshoppers?”).

In the focus group interview, Teacher 15 mentioned that seeing students using the questioning strategy and producing good questions shifted her perception of students as individuals with their own real thoughts and not simply empty vessels needing to be filled by teachers. In the same manner, Teacher 24 said that when she was directing the students back to their questions “student roles changed from absorbing sponge to the one who could decide if the acquired information was enough or not or where/how they should use it.” Teacher 12 shared that when a 1st grader asked, “What happens if the queen bee dies?” she realized the amount of learning and the change in her students’ questions. Teacher 43 said, “The power of turning over that exploration piece to them instead of me ... is more of a developed thing. They’re really thinking... really using skills that they have.”

Theme 2: The Ways Students Perceive They Were Engaged Generating Questions. Over the three weeks that the students were interviewed, there was a shift in their perceptions about questions, who was asking the questions, and what was the purpose of questions.

Initial perceptions. The focus group interviews revealed that most students across all grade levels believed their teachers were the smartest people in their classes

and that was why teachers were asking a lot of questions and knew answers to all of the students' inquiries. "They know a lot about any subject, and they can always answer your questions". Therefore, if a student had any questions, teachers were the people to ask questions of and get the right answer. They also associated asking questions with being smart. For instance during the focus group interview when asked, "Is asking your own questions important?" a first grader responded, "yes, because if you ask a lot of questions then you get smarter." A Second grader and another third grader both said "asking questions makes you smarter." This association of asking questions and smartness is an important insight by students and confirms the literature regarding the use of questions by teachers to elicit a correct response rather than stimulate inquiry and wondering (Mehan, 1979; Sinclair & Coulthard, 1992). Another third graders added that it was ok for students to ask questions when they do not understand something. However, those questions were supposed to be asked of the teacher because "sometimes we get the answer wrong and if you say it to the teacher, she might say that it is correct or it is wrong." Although observations across the classes showed that teachers were engaging students in generating their own questions, these perceptions, which surfaced during the first week, are not surprising given that the teachers during the year primarily follow a didactic instructional format and the IRT questioning approach.

Evolving perceptions. By the end of third week, students began voicing different perceptions. At the beginning of the summer session, when they were asked who asks the most questions in their class, they all said "their teacher". As the days passed with the implementation of the inquiry process, and the emphasis and the guidance of the

teachers that students needed to be the ones asking questions, students began to change their responses. By the second week when they were asked who is asking the most questions in your class, they all said “other students”.

For some students it was clear that they were beginning to equate questioning with learning. For instance a Kindergarten student in the second focus group said, “It is ok to ask question, so you can learn.” They also noticed that asking questions led to other questions, and those questions led to more questions. Another kindergartener added, “When someone is asking a question, I think about that question, and then other questions come to my mind too.” A 2nd grader said that asking questions “makes you smarter because you might get it right and learn it.”

Students reported that asking more questions means they can learn more. A 3rd grader shared, “Asking questions seems like a review in your head. What do you know, and what else do you want to know. If you do not question, you will forget what was important to you then.” Another 3rd grader continued with, “If you don’t ask a question, then it might get out of your head.” This insight shows how she made connection with her own learning. Fourth and 5th grade students both said during the focus group that “asking your own questions help you learn.” Interestingly, for some upper grade students, learning was equated with good grades. Thus, they were secretly hoping that by asking more questions, they could learn better, and get a better grade. Later they realized that there were no grades involved. Thus these students indicated that coming up with their own questions helped them learn because they thought more about the subject. A 1st

grader explained that hearing a question about ants made her wonder about the features of the ants that could make them able to climb the trees.

Students of all grades agreed that “asking questions means you are smarter,” and asking your own questions helps you learn because you are thinking about the topic or the subject. In the last round of interviews we noted an interesting shift in students’ thinking regarding “who” has knowledge to support learning. As students became more comfortable with the trend of the summer school where they were repeatedly given opportunities to generate their own questions, they mentioned that they would like to ask other students questions because they think they can learn from other students. For instance, a 4th grade student mentioned that writing her own question showed her what she does not know, and by working with other students in her group she could tell who knew about it and could ask that student. Most of the students (grades K, 1, 4, and 5) mentioned that asking questions makes you think. For instance, a 5th grader said that asking your own questions is important because you learn the topic. She added: “science is hard and asking your own questions in the science class helps you think more about it and helps you learn.”

Another interesting shift observed was in the types of questions students asked. Table 4.3 presents the questions surfaced by students from charts of questions in the room or from student journals. The questions that students generated at the beginning in our study illustrate their initial search for factual knowledge (recall). Gradually their questions, whether generated individually, in small groups, or posed by the teacher, were replaced by the search for conceptual knowledge, and in some cases replaced with

metacognitive, thought probing questions. An example is the 1st grade students' experience with generating questions. At the beginning, Teacher 15 said students were waiting for her to tell them what they needed to know. When she put on the lab coat and posed as a scientist and started "thinking aloud" (Bereiter & Bird, 1985) to convey what she was doing and what she was thinking, the students were giggling while watching her. Questions from students were not very forthcoming (Observation notes, 07/02/2013). During the next activity when students were observing insects preserved in jars, Teacher 15 wanted them to come up with their questions, which she wrote on a poster board. Students' questions were: "What is it?" or "What do they eat?" Sometimes student responses were not even framed as questions; for example, "Snakes have long tongues."

Table 4.3. Types of Student Generated Questions Based on the IDDL Questions to Guide Inquiry Rubric

Depth of Knowledge	Examples of Type of Questions
Recall What is its function? Is it real or artificial? What is its significance? What is its value?	• What is it? • Why does it have spiky legs? • Do insects have antenna? • Where do they live? • What do they eat? • Who are the predators? • How ocean animals protect themselves? • Where does electricity get its energy? • Are phosphates killing the fish? • How do hummingbirds get nectar and give it to their babies?
Skill What would happen if? Does it always happen like this? What patterns do you see?	• How do they move? • How do insects use their antenna? • How can the earth go around the sun? • How can crab and sea worms live next to volcano? • How can animals survive when there are predators around them?
Strategic Thinking How can I find out about that? How does it work? How does it happen? What affects it? What is the evidence? What does it affect? What assumptions underlie the evidence? What makes the data/facts accurate? What do others think about what said? Do you agree/disagree? Does anyone have the same idea but a different way to explain it? Can you think of a counter example?	• Why are animals becoming extinct? • I wonder how do animals get their water? • I wonder where do animals get their food? • Why do animals need to eat food? • Why do ladybugs have a lot of spots? • How can they put pollen inside the stigma? • Why are some animals getting sick? • How can animals survive in the wild? • Why do insects pollinate? • How does the energy flow?
Extended Thinking about Content How can this knowledge be used to solve other problems? How else might we explain what happened? How do you support your position? Can you convince the rest of us your conclusion makes sense? What would happen if...? What if not? How does this relate?	• How do hummingbirds get nectar and give it to their babies? • How atoms are in everything? • How can we make a pollinator as effective as bees? • How can we best clean up the oil spill?
Metacognition What strategies did you use? How did you think about the task? How did you figure that out? What might you do differently the next time? How did you reach that conclusion? What have you learned that helped you to solve this?	• Why aren't people helping and stopping pollution?

As the students continued their investigations in the next two weeks, their questions evolved from factual recall to reflect more strategic and critical thinking questions. Chin and Brown (2002) explored student-generated questions and showed how those questions were a meaningful facet in learning science. The same phenomenon was observed in this study. Teacher 12 admitted that she was baffled when a student asked about whether or not bees eat their honey. After telling the student and his group that she did not know the answer, she noticed how his group went through all the books in the class and asked to go to the school library in search of finding a response to that question. She said she had these students for the whole year and had never seen them so excited to read the insects books and/or go to the library. She reported: “they could not put the books down”. Later, students came to her and told her that “yes, bees do eat their own honey.” Teacher 12, commented to the observer that students could find their answers in the books and outside the teachers even those questions that the teacher didn't know the answer.

Theme 3: The Ways the Inquiry Prompt Process and 5E Model Support

Science Inquiry. As shown in the case vignettes, teachers implemented IDDL including the 5E lesson model in a fairly consistent way throughout the three weeks of summer school. The IDDL process helped teachers uncover students’ prior knowledge and interests through the inquiry prompt process. The inquiry prompt served to *Engage* students. In the first week of the ELT, teachers played a more direct role in the inquiry process. Teachers were observed using probing questions to guide students’ thinking and exploration of the topic. For example, they asked questions such as “What do you think

about what [student] said? “Do you agree? Disagree? Does anyone have the same idea but a different way to explain it?” They were at the beginning stage of the Inquiry Continuum (Figure 4.2). Their probing questions, however unlike what is typically observed in classrooms (Parker & Hurry, 2007), showed teachers were asking higher order questions, not just factual recall of information. This shift in level of questioning was essential for moving students to deeper understanding as reflected in the Rigor/Relevance Framework (Daggett, 2005).

As students and teachers entered the *Explore* phase of their inquiry, student were observed becoming more engaged in asking the questions and teachers were observed to settle in their role as a guide on the side or activator of learning. This observed shift was supported by the student interview data where students stated that they had started to ask more questions. The observation data indicated variation across classrooms in how actively students were engaged explicitly in the questioning process in the *Explore* and *Explain* phases. As shown in the case studies, the teachers repeatedly engaged Kindergarten, first and second graders as a whole class in generating their own questions throughout the three weeks as they probed, modeled, and used a variety of instructional tools such as Venn diagrams, thinking frames, and science journals, to scaffold the learning toward the final week’s problem-solving activity. Teachers at these levels used the KWL charts repeatedly each week as the students explored a new dimension of their inquiry. In contrast, in the 3-5th grade classes, the teachers began the first week by engaging students in the inquiry prompt, but the process was not repeated. In weeks two and three the students spent more time in small group work exploring solutions to the

problem such as building their ecosystem and examining oil pollution, or exploring different forms of renewable energy. By the end of the third week through a variety of instructional strategies, teachers had students across all grades posing their own questions as they conducted their inquiries (Observation notes 07/15-18/2013).

In the *Extend* phase, across the observed classes, students participated in the small investigation aspect of the Inquiry Continuum, and teachers moved further into the guide role (e.g., 2nd—designing a hand pollinator, 3rd—deciding the best method for cleaning up an oil spill; 4th—finding alternatives to relieve energy poverty).

Figure 4.5 summarizes the data collected from observations and interviews and illustrates the relationship of the 5E model, student and teacher roles during different phases of the model and the different levels of questions that emerged as the model was implemented. The figure is important in showing that teacher and student roles changed as they engaged in inquiry. The final row in Figure 4.5 illustrates the changing nature and depth of questions that students began to ask as they worked through each phase of the 5E Model. Also, through analysis of multiple sources, the type of questions students generated appeared to be the result of the fusion of six factors occurring in the classrooms either simultaneously or sequentially. These factors were: 5E model, Inquiry Continuum, The Rigor/Relevance Framework, Bloom's Taxonomy, teachers' role, and students' role.

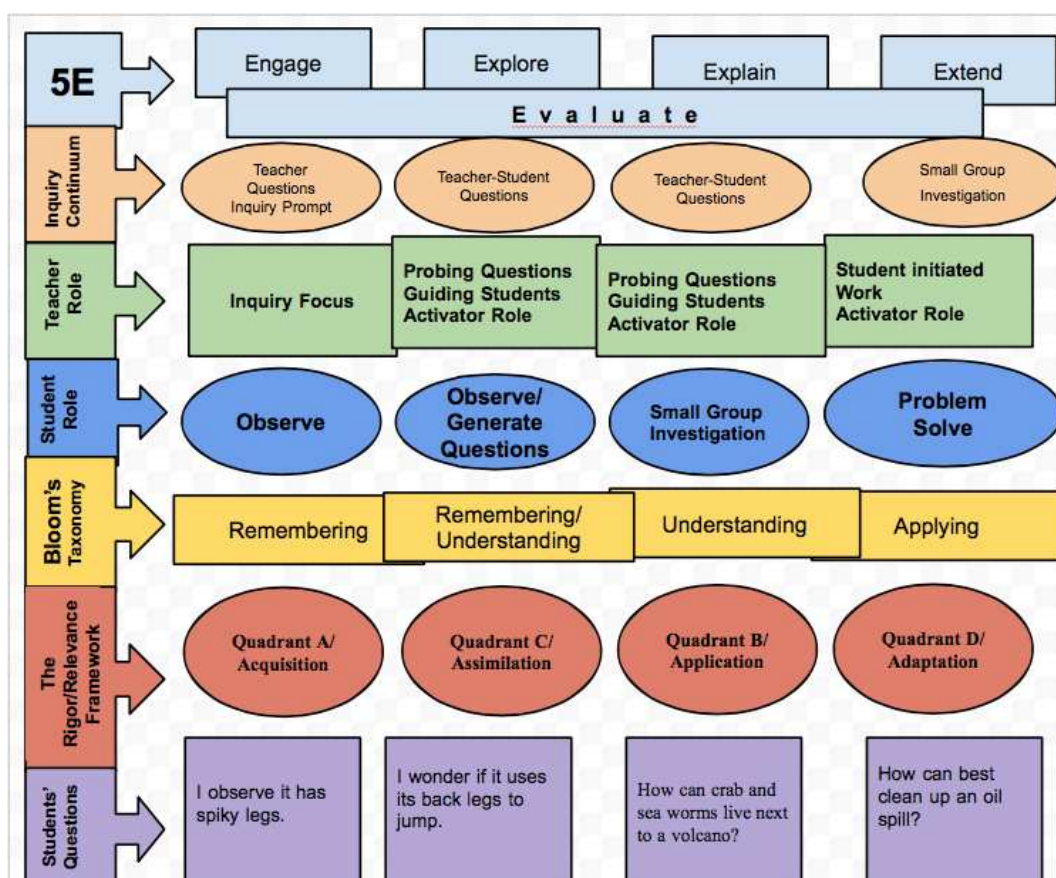


Figure 4.5. 5E, Continuum of Inquiry, and the Rigor/Relevance Framework

As students began generating their own questions, their thinking became more explicit and it shifted teachers' opinions about them as learners. Many teachers agreed that they noticed that students "started thinking outside the box," and showed "a sense of direction" in which they were not relying only on the teacher to provide them with the information and knowledge, rather they were ready to think above and beyond and work on their own learning. This finding is in agreement with Ogle (2009) who said involving students in their learning gives them a purpose.

Viewing teachers' inquiry adoption through the Rigor/Relevance Framework lens, it is clear that teachers stimulated students to work at the Quadrant D level (i.e., they

understood the relevant applications for the science content covered in the summer school). Daggett (2005) emphasized the importance of the right assessment that can help students to achieve the desired level of rigor and relevance. Teachers in this study developed various assessments for students' knowledge acquisition evaluation (i.e., pre-post assessment, journal entries and reflections, monitoring, and observing, final products etc.).

Students increased understanding of science. A review of each grade levels' mirrored pre and post student science assessments revealed an overall shift in their knowledge of the science vocabulary and concepts. The first grade assessment included choosing one of four insects (spider, ladybug, bee, and caterpillar) that they knew something about and to write if that insect feels threatened, how does it protect itself. Most of the first grade responses in the pre assessment selected bee and wrote its means of protecting itself was to sting others. In the post assessments ladybugs and the spider were the insects selected most indicating an increase in their knowledge of a variety of insects and their defense mechanisms. Another question on the first grade assessment asked students to write about how an ant used its body parts after looking at an image of an ant with six body parts labeled. In the pre-assessment most of the writing was about how the ant can use its legs to walk, eyes to see and mouth to eat. However, in the post assessment the level of writing and the knowledge presented showed a change as students wrote about how an ant uses its thorax, antennae and abdomen in addition to writing about the eyes, legs and the mouth. Across the first grade classes it was clear that they

had learned to use the scientific terms and understood more about the role of each body part.

Fourth graders demonstrated their knowledge gains when they both drew and wrote about the renewable energy from the sun, wind and moving water. In their pre assessment the drawings and writing were simple such as we need the sun to get energy. But, the drawing and writing in the post-assessment changed showing that they now understood the connection between each of these renewable energy sources and the production of energy for use by humans. They wrote and drew pictures about solar systems, windmills and turbines driven by waterpower and how each could help to create energy.

When 5th grade students were asked to compare which method of washing a car, on the lawn or in the driveway would conserve more water, students' responses overall showed increased sophistication of language particularly using more scientific terms, such as environment, pollution, runoff, litter, and ecosystem.

Discussion

The purpose of this study was to explore how students become increasingly engaged in their learning as teachers in one elementary school implemented problem-based inquiry during a science-focused extended learning time (ELT). Students' engagement was evident as they generated their questions and worked in small groups towards finding solutions or responses to those questions. In order to provide a better picture of what was revealed from this study, the discussion section is divided into three segments: (1) the connections we observed between 5E model and the Rigor/Relevance

Framework; (2) the types of questions students asked; and (3) scaffolding used by teachers.

5E model and the Rigor/Relevance Framework

Students who were taught and encouraged to generate their own questions, collect data and find answers to those questions demonstrated that they were engaged in the scientific process. Students actively participated in creating new knowledge and augmenting their previous knowledge. Similar to Bain (2004), Chin and Brown (2002), and Schmidt (1983), we found questions raised by students activated their prior knowledge and helped them to construct new knowledge. In addition students' questions were a starting point for their thinking and focused their learning efforts (Ogle, 2009). Because students' questions were directly related to what they were interested in knowing and learning about and assisted them in understanding new scientific concepts while satisfying their curiosity, the questions also gave teachers a better grasp of students' understanding of the science content (Chin, 2002; Keys, 1998). In addition to encouraging students to generate their own questions, teachers also used the schoolyard to promote exploration and make abstract science concepts more concrete and relevant to students' lives. As McCombs (1996) has argued, students from all ages who see the usefulness of their learning and its impact on others, especially in their local community, are more motivated to learn. Similarly, Pintrich and Schunk (1996) have shown when students can see the connection between what they were learning at school and their daily lives, their learning gets deeper. In this study, the example of the 3rd grade students

observing “trash pollution” in their own schoolyard made the oil spill problem relevant and real to them.

Students identified the summer school as a place where they could explore their questions that helped them to understand the science concepts. Data illustrate knowledge construction was the results of three types of interaction: (a) individual students generating their own questions; (b) students participating in small groups where they codified and expanded knowledge through posing questions, discussions, and joint explorations and presentations (Chin, Brown, & Bruce, 2002); and (c) teachers scaffolding the learning path for them while supporting them with their probing questions.

The Types of Questions Asked by Students

Research shows that because teachers are asking 80% of the questions in the classroom (Dillon, 1988; Gall, 1984), students in general do not know how to ask thought provoking questions (Hunkins, 1976), and are not encouraged to generate questions (Parker & Hurry, 2007). Researchers such as Chin (2002), Chin and Brown (2002), Dillon (1988), Hudson-Ross (1989), and Hunkins (1976) support that students need to be taught to generate questions. Interestingly, research provides evidence that teaching students to ask questions can be done in a short period of time (Davey & McBride, 1986). This study adds to the limited literature that teaching elementary students to generate their own questions helps them to engage in their own learning (Roschelle, Pea, & Chapman, 1996). Learning the skill of asking questions was possible even during a short ELT summer session.

As shown in Table 4.3, originally, the majority of questions raised by students in all grades were factual, simple, and exploratory in nature. These types of questions are appropriate and to be expected when students are beginning the study of a new topic. However, if students are to learn and apply what they are learning, as will be required by CCSS and NGSS, they cannot stay at this level as is typically found in most classrooms (Gall, 1970; Kirby, 1992; Parker & Hurry, 2007). Teachers categorized students' questions into two types: simple and deeper questions. The observational data showed and teachers agreed that students started with simple, factual questions at the beginning that arose from their curiosity and basic need to build background knowledge. For instance, "What do ants eat?" or "How do ants move?" or "What is the habitat of a fox?" As teachers practiced the 5E instructional model with their students on a daily basis to engage them in meaningful ways, many opportunities arose for both teachers and students to ask questions. During these practices, particularly during the *Explore* and *Explain* phases, teachers supported students' learning by asking probing questions. Later, and especially under the guided instruction by teachers, students began to change statements into questions when teachers urged them to ask "I wonder" questions, such as, "I wonder where animals get their food," or "I wonder why some animals are getting sick." Soon, the type of the questions students asked reflected deeper levels of knowledge and understanding of the environment such as, "Why are animals becoming extinct," or "Why aren't people helping and stopping pollution?"

Scaffolding of Students' Learning

As the data showed, students initially were reticent to ask questions, perceiving that as the teacher's role. Similarly teachers in this school were also taking on a new role in learning how to encourage student-generated questions. Hill and Hannafin (2001) distinguished between four types of scaffolds that teachers can use especially when undertaking new ways of teaching: conceptual (helping students understand ideas and theories), metacognitive (helping students monitor their own learning process), procedural (helping students build their own tasks and required steps), and strategic (helping students find different problem-solving strategies). All four of these scaffolds were observed in this study and appear to have facilitated the teachers' enabling students to engage in questioning.

Drawing on data from the 3rd grade illustrates the scaffolding process and the benefits for students. During the engineering process, the teachers scaffolded the work for their students by focusing students' sub-questions around a main question to help them see whole/part connections and become more aware of systems. This scaffolding seemed to enhance students' understanding in three ways. First, it assisted students in learning about different content areas and making connections between them. Second, by breaking down a multi-part question into various manageable pieces, the students were able to investigate the question in its parts and the task became more manageable. Third, through taking the role of asking probing, higher order questions the teacher was activating student thinking and exploration rather than giving them answers (Fullan, 2013).

The importance of scaffolding is supported by Vygotsky's theory of the Zone of Proximal Development (ZPD). Vygotsky defines ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (1978, p. 86). The classrooms' problem-based inquiry environment situated students in this study in their ZPD where the zone was defined and created for them by presenting them with challenging problems that they could not solve on their own, but were able to complete in the interaction with other teammates in their small groups and with the teacher and learning resources provided. Teachers monitored, probed, and in some cases, facilitated the collaborative problem solving activities in groups, and through the different types of scaffolding, they helped students to perform at a higher level than they could without facilitation. Teachers also reported significant gains in their students' knowledge and learning about the science topics they were exploring. Summer school and specifically problem-based inquiry classrooms taught students to be inquisitive and take initiative, to search for various ways to approach a problem, locate resources, use information, and be prepared. From their small group participation, students also learned how to negotiate group dynamics and work together to produce a solution to a problem. Thus, significant implications from this study are that through generating their own questions and participating in teamwork, students had the opportunity to work more effectively, to be accountable for their own learning, and realized that they learned better from the real-world issues that they could identify with (Chin & Chia, 2004). For example, when the focus for the 3rd grade classes

shifted from oil spill to trash at their school site, a whole new meaning arose for students about environmental pollution.

Another important facet of scaffolding was that the level of inquiry implementation and activities at each grade level were different based on three criteria: teacher/material guidance, students' independence, and skill involved/developed. Teachers seemed to use various types of inquiry activities as instructional strategies to advance through the Inquiry Continuum (Figure 4.2). First grade teachers, for instance, used inquiry to start their summer classes by modeling investigatory process and using "thinking-aloud" protocol in their demonstrations. With these demonstrations, teachers elicited preconceptions and helped their students learn about the inquiry process. Later, when they had students involved in inquiry lesson by observing and investigating, they continued with their probing questions to enhance understanding, expand explanations, and engaged students in wonderment and predictions. Furthermore, teachers used the 5E model to plan lessons that matched with the Inquiry Continuum and the Rigor/Relevance Framework, both of which illustrated the progression that students and teachers needed to move through to get to deeper and more complex work. As Table 4.3 and Figure 4.5 show, the nature of the questions students explored changed, so did the depth of the questions as well as the roles of teachers and the students. These findings are comparable to Wenning's (2005) proposal of a continuum of five levels of inquiry on the basis of intellectual sophistication and the locus of control. These five levels change as the level of inquiry changes from minimum inquiry to the highest level of inquiry. As one moves away from minimum inquiry and approaches the highest level of inquiry, the locus of

control shifts from teacher to student. Both continua suggest that teacher and student roles can shift in the learning process and that the nature of the work that students engage in can also change in terms of level of difficulty. Ultimately, to engage in real world problem solving, the student must progress to the most sophisticated level of questioning and maximum responsibility for his/her own learning.

Summary

This study examined the third year of an ELT three-week summer school program that took place in the same school for three years. The ELT offered teachers the opportunity to explore the implementation of problem-based inquiry in a relaxed setting without the burden of high-stakes testing. Teachers were open to shifting their teaching to a student-centered approach and were committed to have students use higher-order thinking skills. Teachers changed their roles in their classrooms (Grant & Hill, 2006; King, 1993; Weimer, 2002) and transferred some of their responsibilities to their students when they encouraged them to generate their own questions and find responses to those questions in collaboration with their teammates. The ELT also let teachers consolidate their understanding of a new approach to teaching and develop a collaborative relationship with their grade level colleagues and at the same time encouraged their students in teamwork to support students' engagement in knowledge construction through small-scale investigations.

This study adds to the limited literature on the importance of shifting from teachers asking all the questions to students generating questions as a process to deepen learning and enhance the retention of information (Chin & Brown, 2002; Ogle, 2009).

Also, it shows that under the appropriate circumstances, students learn how to ask and respond to higher order questions (Garcia & Pearson, 1990). This shift is critical if students are to be successful in mastering the CCSS and the NGSS Standards. Using the Rigor/Relevance Framework, the study also contributes by theoretically exploring how knowledge is created, mobilized, and codified within classrooms that are engaged in active inquiry learning. This study agrees with previous research (Davey & McBride, 1986) that teaching students to ask questions can be done in a short period of time, and teaching elementary students to generate their own questions helps them to engage in their own learning.

From this study we can draw four insights. First, having students generate questions is a tool that can easily be used by teachers in implementing problem-based inquiry, and, at the same time can give students a sense of ownership. Thus, student-generated questions are useful in both teaching and learning of inquiry-based units. Second, the inquiry prompt questioning process and the 5E learning cycle instructional model combined were powerful processes for guiding both teachers and students in engaging in problem-based inquiry units that were aligned to NGSS. Third, both teachers and students found the summer school inquiry approach to be an exciting way of teaching and learning science because they felt it promoted both greater engagement and deeper learning of science. Fourth, the ultimate benefit of the ELT summer school program was for the students to recognize the vital role of asking questions in promoting their own learning.

In this study, when students were encouraged to generate their own questions, they were actively involved in shaping effective and productive learning for themselves, which in turn validated teachers' hard collaborative work in providing them with the problem-based inquiry environment, curriculum, and assessment that were tied to the CCSS and NGSS. Teachers strove to create a rigorous and relevant education for their students in this case and Daggett pinpoints this education as a "product of effective learning, which takes place when standards, curriculum, instruction, and assessment interrelate and reinforce each other" (2005, p. 1).

When students are engaged in the learning process, real achievement takes place, and their chances to excel at what they do increase. Often, all that is required is a change in the attitude and the willingness to reconstruct education so that it prepares students for life (Daggett, 2005, p. 2).

Future Research

This study raises several avenues for future research. One area for further study is to understand if teachers are able to implement these questioning strategies into other aspects of their teaching during the regular school year with more traditional approaches to textbook teaching. It would be valuable to know what are the supports and constraints at the school level for these teachers to continue the Inquiry Prompt process during the year, and to follow students during the school year to see if both teachers and students continue the process of students generating questions.

Another area for research would be conduct an experimental study to better understand the cognitive impact on students learning by comparing student outcomes in classes where students are taught to generate their own questions with classes where they do not engage in these practices. Do students master the standards as well? Are they

more or less engaged in learning if they pursue inquiries linked to standards as opposed to more didactic teaching of the standards? Further study is also needed to know how much professional development is needed for teachers to effectively and consistently make this shift in having students generate their own questions. It would also be important to know how to help teachers foster more metacognitive questions that both they and students might pose.

Chapter 4, in part is currently being prepared for submission for publication of the material. Nariman, Nahid; Chrispeels, Janet; and Karwan, Vanessa. The dissertation author was the primary investigator and author of this material.

Endnotes

¹Turnaround model selected by this school required the district to select a new administrator who in turn replaced over 2/3 of the former classroom teachers. All teachers in the district could apply for and all, including current teachers at the school, were interviewed for these positions.

CHAPTER FIVE: CONCLUSION

This chapter summarizes the results and findings of this study. Later, these findings will provide a roadmap to propose implications and suggestions for areas of future studies. The chapter begins with a summary of the problem and the conceptual frameworks, a review of methods, and a summary of the findings. Conclusions drawn from the results are discussed in relation to the literature review and implications for policy and practice as well as identifying the areas for future research are described. Finally, the chapter finishes with concluding remarks.

Overview of the Problem

With the adoption of new curriculum content Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) in the United States, one critical issue that needs to be studied is the instructional strategies that are being used to help students master these new standards and teach students 21st century skills. Recent research testifies to resurfacing problem-based inquiry instruction in various grade levels. Although the benefits of creating an inquiry environment, particularly in science classes have long been recounted (NRC, 1996), the research showing its usage at the elementary level is scarce. Earlier studies have shown how problem-based learning environments have improved student research skills (Gültekin, 2005), and are effective in developing students higher order thinking (Horan, Lavaroni, & Beldon, 1996; Shepherd, 1998; Wolff, 2002). Less research has been conducted on identifying the challenges and benefits of implementing problem-based inquiry in elementary science lessons (Crawford, 2000; Etherington, 2011; Osborne & Freyberg, 1983; Tandogan & Orhan, 2007).

The primary purpose of this study was to examine the implementation of problem-based inquiry science lessons during an Extended Learning Time (ELT) summer school. This study of a single elementary school represents a unique case that has used the *Turnaround* requirement to offer an ELT program in order to take steps toward implementing a problem-based inquiry approach that would support teachers to shift to more student-centered classrooms. This study was conducted over the last two summers of a three year ELT. In the second year of the ELT, as part of a research team, I investigated challenges faced by teachers as well as the benefits perceived by both teachers and students when the teachers implemented problem-based inquiry in an ELT summer school session. In the third year of the program, I researched how teachers engaged students in generating their own questions and how they used the 5E lesson model to engage students in problem-based learning. Data and participants' reflections were obtained using semi-structured interviews of teachers, focus group interviews of both teachers and select students, and observational field notes from the classrooms and teachers collaborative meetings. A key concern was to understand where the challenges were and what steps were needed in order to ease the shift to a student-centered classroom for both students and teachers. A second major issue was the impact on student's engagement with science when they were taught how to generate their own questions.

Research Questions

The research questions that guided this study in Phase I were:

1. What challenges do teachers face in shifting from a teacher-centered didactic approach to student-centered teacher facilitated learning?

2. What are the benefits of shifting from a teacher to a student-centered approach?

Phase II research questions were:

3. How do teachers stimulate inquiry and enable students to generate their own questions?
4. In what ways do student perceive they were engaged in generating their own questions?
5. In what ways do the IDDL Inquiry Prompt Process and the incorporation of the 5E model support student science inquiry?

Conceptual Framework

Two interrelated concepts—distributed cognition and constructionism—framed this research and created a foundation upon which preliminary research questions were placed. Constructionism that is multidisciplinary in nature drew its influence from philosophy, psychology, and sociology (Kang et al., 2007). Constructionism claims that learners actively construct meaning and the reality of their world in and through social interaction with each other and with the teacher in an ongoing and dynamic process (Berger & Luckman, 1967; Jonassen, Peck, & Wilson, 1999; Kafia & Resnick, 1996; Spodark, 2005; Wheatley, 2007). This means that knowledge is built and not supplied, and the construction of knowledge happens best when individuals are engaged in building something together that is external and shared.

Distributed cognition recognizes the social interactions and setting in which knowledge is shared (Hutchins, 1995a, 1995b). Distributed cognition systematically explores how cognitive activities are distributed across groups through social

interaction, time, and artifacts. Distributed cognition provides a lens to understand the organization of cognitive systems from the outside in, “beginning with the social and material setting of cognitive activity, so that culture, context, and history can be linked with the core concepts of cognition” (Hutchins, 2000, p. 10). According to Hutchins (2000) cognition is about information processing and “passing”— the process of information being passed between individuals and artifacts to accomplish a task or goal. When a real world problem is of concern information is processed and passed between and among individuals and the instruments (artifacts) in the variety of feedback loops used to ensure safe steerage. A distributed view of learning can shed light on the critical role that artifacts play in the construction of knowledge.

Further, the Rigor/Reference Framework was used to help me understand whether teachers were changing the quality and nature of their instruction to be more rigorous. This framework examines curriculum, instruction, and assessment based on two dimensions of higher standards and student achievement. It is based on two continual (Bloom’s knowledge taxonomy, and the application model) represented by a four-quadrant model (see Figure 4.1). Daggett (2005, 2008) argues that the educational system in the United States has not kept up with the changing nature of work, enhancement of technology and the competitive job market despite educators’ efforts. He also suggests that this framework can serve as a bridge between the community and the school to demonstrate to parents, community, and business leaders how students are developing 21st Century skills and learning how to learn. In this study, the above framework served as a tool for analyzing the observed lessons that teachers engaged students in during the summer session.

Review of Methods

This study used a single exploratory case study design (Creswell, 2008; Yin, 2003). It focused on one single school serving over 700 students who were predominately socioeconomically disadvantaged and English learners. This school was engaged in a three-year Turnaround process and adopted an Extended Learning Time (ELT) summer session as part of its reform strategy. Therefore, a single case study design using multiple data collection methods seemed most appropriate. The data collection method for this study consisted of two phases. In both phases quantitative and qualitative data were collected from multiple sources. In phase I (Year 2 of ELT, summer 2012) quantitative data included students' pre and post teamwork survey. Qualitative data for this phase included: semi-structured interviews with 18 teachers, teacher lesson plans, classroom observation notes from three 4th and three 5th grade classrooms, and student work samples of formative assessments and final products. The analysis of the data from Phase I surfaced patterns of student-teacher engagement that raised further questions. I shared the data from Phase I with the faculty and Turnaround Coordinator, which were then used in planning the third year of the ELT. This sharing of data and subsequent redesign of the summer school program created a rich opportunity for me to continue researching the summer school program.

Phase II (Year 3 of ELT, summer 2013) consisted of collecting both qualitative and quantitative data, such as a teacher survey, student focus group interviews, teacher focus group interviews, students' artifacts, teacher weekly lesson plans and collaboration and team planning minutes, classroom observation notes, and coaching notes.

For both studies qualitative and quantitative data were used to triangulate the

findings and to explore emerging themes and categories in greater depth. Identification and connection of the themes was investigated through a continuous comparative analysis. In addition, the theoretical lenses of distributed cognition, constructionism and the Rigor and Relevance Framework provided insights into the challenges of teachers rethinking their instructional role and were used to structure an understanding of the shift from teacher to student-centered classroom environment.

Summary of Findings

Phase I summary

The first set of findings from this study were based on the Phase I data (Year 2 of ELT, summer 2012). Five major challenges were identified: time, technology, students' lack of experience with teamwork, students' lack of experience with inquiry learning, and the challenge of shifting to a student-centered learning approach.

1. Time. Time emerged as a major barrier to inquiry learning in all the interviews. Teachers mentioned three components of time that they had challenges with: time to collaboratively plan their inquiry units; time to develop curriculum, especially finding resources and researching what they were to teach; and time needed for students to fully engage in inquiry.

2. Technology. With technology and its use, three issues emerged. First, teachers expressed a concern that they didn't have the technology research tools at the English language levels of the students (they suggested that the tools were too advanced). Therefore, they were concerned about finding appropriate, kid-friendly Internet sites that provided information in an "easy-and simple" format for English language learners to understand. For teachers, it was important that their students find information and to be

able to distinguish between “good” and “bad” information. Second, there were several teachers who did not incorporate technology due to their individual discomfort with technology. They would refer to their own lack of knowledge in using technology as impeding their abilities to direct and guide their students. Lastly, although teachers of all grade levels used the teacher laptop and the document camera to present videos and PowerPoint presentations to the whole class, a few part-time teachers claimed they had no access or restricted access to iPods and indicated this was challenging for them.

3. Students’ lack of experience with teamwork. Teachers were introduced to Kagan cooperative learning structures as a way to build student-learning teams (1994). Nevertheless, the review of the data showed that teachers attested to teamwork being a challenge. Classroom observations confirmed the teachers’ perceptions that for students it was not easy to feel and be part of a team. It took them a while to realize that their traditional learning and teaching environment had changed for the summer school. Students did not know how to behave in their teams and needed constant direction and reminders from their teachers as they started to work together to find solutions for their science problems. Many teachers also felt that students were not prepared to respond to ‘how’ and ‘why’ questions. Teachers from all the grade levels itemized various ways students struggled with the teamwork. Classroom observation also corroborated this struggle. An insight from these observations also suggests that the instructional tasks given to the students did not require all students to contribute. There was a lack of both rigor and complexity in the learning tasks that is needed for effective cooperative learning (Cohen, 1994).

Although teachers described how hard it was for the students to become an active part of a team, later on they realized how constructive teamwork turned out to be. Students' surveys on teamwork also identified that despite all the struggles students encountered adjusting with their teams and teamwork, it was their teamwork at the end that they valued the most.

4. Students' lack of experience with inquiry learning. Implementing an inquiry-learning environment was challenging for teachers and at the same time it created numerous challenges for students. Students who had grown accustomed to didactic instruction started the summer school expecting to be "spoon fed by teachers." Teachers tried to break that habit by implementing inquiry into their lessons. Several teachers agreed that it was hard for them to teach students how to "listen," "come up with their own questions," and "stay engaged."

A related issue was teachers' perceptions that students could not express their thoughts in writing or orally. Teachers attributed this expressive weakness to students' lack of experience in being in charge of their own learning and in developing their own questions. The post summer school interviews indicated that teachers were beginning to understand that the traditional modes of teaching they used during the year created passive learners. Classroom observations, however, also confirmed that teachers continued to use "fill in the blank" instructional approaches that required little investigation, thinking or writing. Students also confirmed that writing was a challenge. In the pre-survey when students were asked an open-ended question about what they expected to be the hardest thing about working in teams, interestingly the item with the highest number of responses was "writing."

5. The challenge of shifting to student-centered learning. The habitual use of didactic instruction put a strain on teachers in shifting to a student-centered inquiry approach. The barriers that emerged included a lack of experience with inquiry teaching and the unwillingness of letting go and allowing students to work more independently and collaboratively. Teachers' lack of experience with inquiry served as a major barrier. Using inquiry was regarded as "a change in mindset or a paradigm shift." Teachers felt that a lot of schools were in the same situation where teachers used didactic instruction as required by federal and state mandates. Therefore, switching to inquiry required a major shift in thinking for both the teacher and students. Nevertheless, teachers agreed that stepping away from the routines of their previous ways of teaching was important. Their summer experience showed them that students were more engaged in the inquiry environment and learned more. One teacher summarized it as, "I do think any time the kids can be engaged and excited about their own learning, they pick it up faster, take more, remember more, and retain it."

Another major issue coming from the data was how hard it was for teachers to let go and give students permission to explore and do their research. Teachers mentioned it was not easy to control themselves and that inquiry was not in their "comfort zone." Though hard and difficult to let go, teachers tried because they saw its benefits.

After sharing these findings with school administrators and teachers, several changes were implemented for the 2013 summer school session. For example, the time issue was addressed for 2013 summer session by starting earlier in planning the units that would be taught. Teachers selected the standards and created problem scenarios with their grade level teams before the summer school program. More materials and resources

were ordered for each grade level. In addition, daily collaborative planning time of an additional hour was built into the schedule. Also, it was decided that teachers would retain the same students for the next summer school session whenever possible.

Furthermore, another insight from Phase I research was the need to increase student engagement. Thus, the planned professional development for the 2013 summer school focused on teaching a process that encouraged and enabled students to develop their own questions. The explicit instruction in questioning was found to be a vital first step in helping teachers shift to a more student-centered classroom. In return, it identified and validated the importance of the invaluable input from the participating teachers in improving the summer school through planned adjustment.

Phase II summary

The second set of findings from this study was based on Phase II data (Year 3 of ELT, summer 2013). There were three overarching themes observed in the second set of data: (1) The ways teachers stimulated inquiry and enabled students to generate their own questions; (2) The Ways students perceived they were engaged generating questions and (3) The ways the IDDL Inquiry Prompt process and 5E Model supported science inquiry.

1. The ways teachers stimulated inquiry and enabled students to generate their own questions. To stimulate inquiry, teachers started summer school with a collaboratively developed standards-based science unit. Teachers collaborated with their grade level team and wrote an inquiry prompt and discussed their inquiry implementation plan. This, coupled with the training they received during the week-long professional development time on how to teach students to generate questions and incorporate the 5E instructional model in their instruction, paved the road for smoother implementation of

problem-based inquiry in their classrooms. This in turn, shifted their perceptions of their students as individuals with their own real thoughts. Teachers noticed their students' role of passive learner shifted to an active participant in their learning who could discuss their point of view with their peers and decide how to use their acquired information.

2. The ways students perceive they were engaged generating questions.

Interviews with students revealed that their initial perception was that smart people ask a lot of questions. Since their teachers were asking a lot of questions and could always answer any questions, students considered their teachers to be the smartest people in their classes. As teachers went through implementing stages of teaching students how to generate their own questions, distinguish between the open and closed ended questions, and at the same time gave students plenty of opportunities to practice creating their questions, students realized that the more questions they asked, the more involved they were in their classes and the more they learned. By the second week when students were asked who was asking the most questions in their classroom, they all said other students. For some students it was clear that they equated questioning with intelligence as well as learning. By the end of the third week, students of all grades agreed that asking questions meant they were smarter, and asking their own questions helped them learn.

Furthermore, a shift in thinking regarding who has knowledge to support learning was also revealed in the last round of interviews. This shift revealed itself when students who had repeatedly been given the opportunity to generate their own questions posed their questions to other students, thinking that they could also learn from them as well as from the teacher.

3. The ways the IDDL Inquiry Prompt process and 5E Model supported science inquiry. Teachers used the 5E instructional model (engage, explore, explain, extend, and evaluate) consistently throughout the three weeks of summer school (Bybee et al., 2006; Karplus & Theire, 1969). As teachers worked through each phase of 5E, it helped them identify students' prior knowledge and supported students to make sense of what they were learning. While implementing the 5E phases, teachers reported and they were observed playing a more direct role at the beginning of the summer school due to their previous habitual way of teaching. However, as the teachers engaged students in generating questions and implementing their 5E lessons, they provided students with probing higher order questions, opportunities for students to ask questions and to explore their interests. This shift in the level of questioning and exploration was essential for moving students to deeper levels of understanding as reflected in the Rigor/Relevance Framework (Daggett, 2005). As students and teachers entered the *Explore* phase of their project, students became more engaged in asking higher-level questions and teachers took on the role of facilitator and activator where they guided student learning. This observed shift was supported by the student interview data; they reported they were now asking more questions. The observation data also revealed variation across classrooms in how actively students were engaged explicitly in the questioning process in the *Explore* and *Explain* phases. In the *Extend* phase, across the observed classes, students participated in the small investigation aspect of the Inquiry Continuum, and teachers moved further into the guide role (e.g., 2nd—designing a hand pollinator, 3rd—deciding the best method for cleaning up an oil spill; 4th—finding alternatives to relieve energy poverty). The *Evaluate* phase took place throughout the cycle as well as during students' final

demonstration of their mastery.

Conclusions

Six major conclusions were drawn from this study. First, in agreement with Vratulis, Clarke, Hoban, and Erickson (2011), the challenges that teachers faced in implementing a new instructional model did not let them take full advantage of a new instructional approach. In this study, teachers revealed that they still had a fear of “letting go.” This finding is similar to Thomas’s (2000) argument that teachers need to find balance between student control and teacher control in a project-based learning environment. It appears, as Grant and Hill (2006) and King (1993) discussed teachers need to accept their shifting role in their classrooms from the “sage on the stage,” to facilitator and activator on the sidelines. This shift in role is needed to give students greater responsibility for their own learning. For teachers to shift their role and transfer more responsibility to students, they need time and practice in implementing problem-based inquiry—a challenge surfaced in Phase I of this study. To solve this issue as it was demonstrated in Phase II, planning for the summer school earlier during the year gave teachers another chance to construct new knowledge for their practice and their shifting roles (Grant, 2002).

A second conclusion drawn from this study was that team collaboration proved to be beneficial for both teachers and students. Phase I results demonstrated that despite students’ struggle with teamwork and inquiry, by the end of the summer school session they learned some science, and ways to collaborate and participate in teamwork. This is in agreement with Roschelle et al.’s findings (2000) about the benefits of inquiry and teamwork. In Phase I teachers also had an opportunity to engage in joint planning.

These collaborative practices for both students and teachers were continued in Phase II. The results showed that students continued to develop their teamwork skills. Teachers also, through collaboration, developed their knowledge and comfort with the problem-based inquiry implementation. These findings illustrate the importance of collaborative learning and group work practices for teachers and students, as they are equally required to accept the shift in their roles to engage in inquiry learning.

Third, related to Ravitz's conclusion that even when teachers show enthusiasm for implementing a teaching approach after professional development, they might not find it easy to implement (2003). Phase I of this study revealed that teachers did not find implementation of problem-based inquiry easy despite being very interested in bringing it to their classrooms. However, based on the insights learned from the findings of that phase, the planned professional development for Phase II made it possible to provide specific guidance and support to teachers. For instance, the focus of the professional development in Year 3 ELT was on training teachers in using an inquiry prompt to assist students to generate their own questions and a 5E instructional model, which was in direct response to what was needed to help teachers and students to ease into an inquiry approach.

Fourth, similar to previous studies on valuing student-generated questions (Chin, 2006; Parker & Hurry, 2007), this study also found that students were motivated to learn when they had the opportunity to generate their own questions related to the NGSS standards selected by the teachers. Within this context they pursued their interests and curiosity while at the same time understanding required scientific concepts. Student questions also gave teachers a better grasp of students' understanding of the science

content (Chin, 2002; Keys, 1998). Chin and Brown (2002) explored student-generated questions and showed how those questions were a meaningful facet in learning science. This study, as data revealed, also presented how generating questions helped students to develop more interest in learning science.

Fifth, by collecting data over two consecutive summer school sessions, it was possible to grasp the implementation trajectory of inquiry as teachers collaboratively learned how to design, implement and teach problem-based inquiry to their students. This study showed how critical professional development, time for repeated practice and a non-high stakes testing environment was for teachers to change instructional practices.

Finally, artifacts particularly technology, played a critical role in this study. Although technology was heavily implemented at this school site and the expectation from the administration was to see it being used, there were some factors that led to it not being used appropriately. Teachers' lack of comfort with using and incorporating technology in their classes/lessons, and their difficulties in identifying the appropriate kid friendly websites for their students were major inhibitions in exploring the advantages of technology as a learning and research tool.

Implications

The overarching problem that I sought to address through this study was the implementation of problem-based inquiry in elementary science lessons. With the enactment of Next Generation Science Standards (NGSS), it is an excellent opportunity for teachers to bring science back into elementary schools through implementing an inquiry-based science program where students are actively involved in their learning.

The findings of this study have implications for future practice, policy, and theory. The following section presents a discussion of these implications.

Implications for Practice. This study has five implications for teacher professional development (PD) and pre-service education. Reform at all levels led by the NGSS focuses on deep learning, which can be fostered through empowered and facilitated knowledge co-construction by students and teachers. An inquiry-based, student-centered classroom supports knowledge creation and learning for all students. As this study exemplified, using a student-centered approach such as problem-based inquiry gave students access to NGSS standards and an opportunity to learn basic science concepts in an engaging way. Based on the data, there are several initial steps districts and schools can take in shifting to a student-centered approach. First and most urgently, there is a need to acknowledge that the didactic, teacher-led modes of instruction and the heavy emphasis on language arts and mathematics have provided limited opportunities for teachers to engage students in inquiry or in science (Hattie, 2009). The new Common Core and NGSS standards cannot be successfully implemented if students are not actively engaged in constructing knowledge with teachers and their peers. District and school leaders need to plan for success. Teachers in this study indicated the importance of this approach in their responses to interview questions where they identified student-centered learning the best way for students to learn.

Second, this study shows the power of teacher collaboration in developing NGSS aligned inquiry units. However, it is also clear that teachers must be given more time and space to do this work. One possible solution to the time conundrum would be to have teachers work in collaboration to adapt previously developed units that now

need to be aligned to the new standards. Engaging in this process a few times is likely to greatly facilitate teachers' ability to create units from scratch.

Third, the involvement of school administrators played a crucial role in this study. The report of the Phase I results provided the school leaders and administrators an opportunity to bring theory and practice closer together by incorporating subsequent changes in the structure of the Year 3 of summer science program 2013. Prior to Phase II of the study, teachers realized that their concerns were not only considered by the school administrators, but also had set actions into motion where the challenges they encountered and the benefits they observed had given the school administrators a roadmap for planning for the next summer school. With those obvious changes in place, teachers knew that their voices were not only heard, but also that school administrators were aware of the challenges they faced within the early implementation period. As it is clear, school administrators and leaders need to be involved and supportive of needed changes in their school site.

The fourth important issue was the realization that there was a need to invest in suitable and appropriate PD that scaffolds primary steps in early phases of implementation. The new standards such as CCSS and NGSS, and the pedagogical approaches they require, suggest that teachers cannot continue to do business as usual. It is essential that pre-service programs and PD be designed in ways that mirror the way teachers are to lead their classrooms. Realizing that change goes through normal stages and takes time, it was imperative to introduce new knowledge in steps and in ways that teachers can adapt and build upon. When teachers and educators learned how to scaffold their initial steps, they could create scaffolding initiatives that better allowed for the

necessary time to enact change. In this study, I have shown how introducing the Inquiry Prompt Process and 5E provided the necessary scaffolding teachers needed to take their work to a new level of sophistication and student engagement. The voices of both students and teachers in this study added to the previous research in this field by clarifying the kinds of support both needed to successfully implement problem-based inquiry. These supports included more knowledge and skills about how to work as teams, the importance of posing a full range of questions by both teachers and students, the importance of having adequate and the right resources and artifacts for authentic and relevant investigations.

Finally, teacher preparation programs and professional development must engage teachers in exploring their role and relationship to students (Barell, 2010; Ertmer & Simons, 2006). How can teachers be guided to reflect and reframe their perspective from the “sage on the stage” (King, 1993) to a facilitator and activator of learning (Fullan, 2013; Hattie, 2009)? An important first step is for teachers to examine their own questioning strategies and to shift from asking primarily factual and inferential questions, as is now typical, to asking probing and higher order questions such as how, why, analysis, strategic, and reflective questions.

Implications for Policy. This study also offers several policy implications, particularly for policy makers interested in effecting large-scale improvements in the construction and development of 21st century skills and competencies in students. Previous studies have identified the crucial role of the 21st century skills for success and survival in the global marketplace (Darling-Hammond, 2010, Dede, 2009, Fullan, 2013, P21, 2009). Students in this study mentioned how learning to generate their own

questions helped them to be smarter and learn better, and working with other students in small groups helped them value teamwork, collaboration, and problem solving processes. An implication for district policy is establishing assessment policies that include both student individual and team exhibitions, which demonstrate mastery in collaboration, cooperation, and problem solving as well as knowledge in a critical content standard as a requirement for moving to the next grade level.

Districts are in charge of not only interpreting but also implementing new standards such as NGSS, which in turn influences and drives its reform practices. This study is timely in that it highlights challenges teachers face such as time for planning and professional development needs that districts, which are in the process of developing implementation strategies for CCSS and NGSS can use to make informed decisions. Findings from this study suggest two major areas for further elaboration by districts. First, is the need for elementary teachers to develop their science content knowledge if they are to be able to design effective problem-based units aligned to NGSS standards. Districts can support this knowledge development by creating opportunities for high school science teachers to mentor and adopt grade level teams as they develop their science units. Second, district leaders need to provide professional development at the district and school levels that helps teachers use technology not just as another textbook, but as an integrative tool for creating and storing knowledge as students interact with their environment and real world problems. A quick glance at the way technology has expanded and has affected the learning habits of today's students as well as a glance at school and district regulations controlling the usage of technology at school sites has made it highly likely that deficiencies already exist in how to integrate technology in

classrooms. Incorporating and integrating technology in everyday lessons must be implemented quickly in order to be able to raise students who are capable and able to compete at international benchmarked standards. Using student-centered instruction should be accompanied with the integration of 21st century technological tools in order to create mechanisms in the school/district that align practices with a changing educational environment.

A third implication for policy from this study is the need for sustained and coherent professional development. Too often districts change the PD focus each year with inadequate time for teachers to explore, learn, and then practice new skills to ensure they reached mastery. The findings of this study revealed that when PD is aligned with teachers' needs, the result is positive change in instructional practices and approaches to learning.

Also, the findings of this study showed how students were involved in learning of science through generating their own questions while at the same time learning about cooperation and collaboration with other students as they solved problems. Teachers offered support by providing probing questions and leveraging some of their power in the classrooms to their students. Such small changes could lead to big impact on student motivation to learn and their desire to achieve. The shift to student-centered classroom required a change in teachers' practices and classroom management. These paradigms shifts cannot happen unless school boards and district administrators support teacher evaluation policies and student assessments that encourage opportunities for risk-taking and reward innovative practices in which schools are demonstrating student mastery in a

variety of ways. A first step would be to especially encourage a variety of ways students could show mastery of content standards in science and social studies.

A final policy implication is to explore the possibilities of offering summer school where the focus of instruction can be narrowed to science, for instance, to provide teachers with an opportunity to put their learned skills into practice in a more relaxed environment. In this study, teachers, by returning each summer, showed their readiness and desire to shift their practice from teacher-centered to student-centered learning given the opportunity to learn and practice these skills in the summer. Also, students identified that they learned from their teacher and fellow students during the course of the summer school session. In addition, the support of the school administrators to provide resources, listen to teacher perspectives, and modify each summer's program based on teacher feedback helped to make the summer program a success. The administrators realized that teachers needed time and resources to be able to explore the implementation of problem-based inquiry more deeply. Thus, administrative support came in the form of providing staff with professional development, including paid collaboration time and extra resources.

Implications for Theory. The findings from this study identified several implications for theory. Current and future educators would benefit from a deeper understanding of the theoretical constructs of constructionism and distributed cognition. Fully understanding the social nature of learning, combined with the practical knowledge of how to build strong student teams that are able to tackle complex, messy problems (Cohen, 1994; Kagan, 1994; Slavin, 1990) would greatly facilitate the implementation of problem-based inquiry (Burke, under review). Knowledge of

distributed cognition would enable teachers to think through how artifacts and students' interaction with artifacts are central to learning. The concept of artifacts is especially important as teachers learn how to more effectively integrate technology not as another "textbook" but as a social learning tool that allows students to become knowledge builders and not just consumers (Edelson et al., 1999; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989).

With the opportunity of providing the school administrator with a Year 2 Extended Learning Time report after the summer of 2012, this study moved into a design-based research format. It became extremely clear during this study that research and practice need to move hand-in-hand, particularly when it comes to taking initiative in implementing new standards and policies as this school attempted. The design-based research and practice created an environment of trust between me (the researcher) and teachers (the participants). I was welcomed into their classrooms, as my presence was not considered as a threat, but rather an observer that could give them voice in my reports. Design-based research offers doctoral students a research approach that can both support research as well as help schools and districts improve practices through a feedback loop as was implemented in this study.

Additionally, the prospect of the research, for me, was to be able to view the classroom observations, interviews, and documents through the lenses of either constructionism and/or distributed cognition. It was through these lenses that I could identify the critical role of social interaction amongst students, students and teachers, and students and their artifacts. Through continuous discussions with teachers I was able to show to them how the learning environment was a combination of their relationships with

their students and students work in their small groups with other students and/or artifacts. Their role as a teacher was to be supportive of student learning and to facilitate more learning through probing questions and extended opportunities for group discussions. Support for student learning came from teachers' questions moving from initial/recall questions to more conceptual ones, and through the Rigor/Relevance Framework where classroom instructions and curriculum moved from quadrant A to quadrants B and D.

Another key to success for all students was guiding them through the phases and steps of the IDDL inquiry Prompt Process towards leading them to be in charge of their learning. Learning to satisfy their curiosity through inquiry-based instruction that identifies with mastery-based learning is considered the major components of today practices.

Limitations

This study was conducted in an elementary school in southwestern United States. No sampling was done in this study; rather all the participating teachers were interviewed. Due to the nature of a single case study, the findings and conclusions are not generalizable to other settings. Furthermore, the summer school program is different from the regular school environment. Findings may be distinctive to this unique relatively small case.

Nevertheless, through the theoretical lens of distributed cognition, findings from the study about the importance of artifacts in the construction of new knowledge are applicable to other settings. Similarly the understanding of the constructionism as an approach to learning that supports inquiry is also relevant beyond this particular study.

Areas for Further Research

This study is among the first to examine the implementation of NGSS. It demonstrates how problem-based inquiry and appropriate professional development based on teacher input can prepare teachers to embark on shifting instructional practices to be more student-centered. We can make this case stronger by expanding the study to include other schools offering similar or different types of summer school programs to understand the effects on both teachers and students. More research is needed to investigate how problem-based inquiry could support implementation of NGSS.

Since this study was unfolded in an ELT during a summer school, a question remains as to how this implementation will unfold during regular school instruction. More research is needed to follow these teachers and students during the regular school year to observe whether they continue the process of students generating questions, or whether they fall to traditional patterns when the teachers again base their instruction on textbooks and didactic teaching.

Also, this study contributed to the literature on constructionism and distributed cognition. Further research would benefit these theories by conducting similar research in an area with a different student population. Such a study might provide additional insights on what supports or constrains the implementation of problem-based inquiry in different settings. Furthermore, a longitudinal study on the same issue would add to the body of knowledge on problem-based inquiry in an elementary setting. It would also be interesting to learn how the structures for knowledge construction shape or change in a student-centered inquiry environment. Such a study would provide policy makers,

districts, and schools with recommendations on best practices for fostering student-centered inquiry classrooms.

Concluding Remarks

Presently, education in the United States has encountered the dilemma of dealing with a minimal operating budget while at the same time evaluating students' achievement with higher accountability standards. The adoption of CCSS and NGSS has amplified the rigor of subject matters for all students and has increased the demand for student-centered approaches for the classrooms. As the educational standards have changed in the United States, educators are expected to learn these new sets of standards. The CCSS and the NGSS standards that have been adopted are more rigorous than previous standards, and are encouraging administrators and teachers alike to work together towards finding effective ways of ensuring mastery that engages students more actively in learning and increases their preparedness for college and careers. To be able to do this, teachers must be open to shifting to student-centered classrooms and adopting new roles as facilitators and activators for learning. As teachers become more skilled in constructing and sharing knowledge, they will become better in their new roles and more competent in solving problems of practice.

Appendix A

Interview questions for teachers

Summer 2012

Introduction: Thank you very much for agreeing to meet and talk with me about your experience of the summer school and implementing problem-based inquiry. Your insights will help us to know what were the benefits and challenges in implementing problem-based inquiry unit.

1. What was the main reason for your participation in the extended summer science school (from now on, I will refer to this as summer school)?
2. You did a unit on food chain and food web. What was the most exciting part of teaching this unit?
3. What was challenging *for you* in implementing this unit?
4. What was challenging *for the students* in doing this unit?
5. What do you think the students learned from this Inquiry unit? In terms of:
 - a. Science content
 - b. Scientific processes
 - i. Observing
 - ii. Note-taking
 - iii. Problem-solving or carrying out an investigation
 - iv. Ability to explain what was happening
 - v. Coming up with the solutions for problems
 - vi. Developing their presentations/final projects
 - c. Do you want to share a memory?
6. If you were doing this unit again, what changes would you make, if any?
7. A key part of problem-based inquiry is teamwork. I noticed that you used heterogeneous groups. Have you used small groups or learning teams during the regular school year?
 - a. Tell us what was the strength of the teamwork during the summer?
 - b. What did students learn being a member of a team?
 - c. What were some of the challenges?
 - d. How will you change the teams?
8. We observed you integrating technology in your class during summer school, tell us how did that supported student learning?
 - a. Were there any parts of technology more helpful than the others?
 - b. What were the challenges to incorporate technology?
9. What did you learn being part of a teaching team yourself?
10. How do you evaluate your own knowledge of science?
11. How do you evaluate your team members' knowledge of science?
12. Any "Aha" moments for you? Any regrets?
13. In moving towards the implementation of Inquiry units what was the most helpful in the inquiry training you attended?

- a. Working with the same grade level teachers?
 - b. Being able to start a unit of Inquiry and work on it?
 - c. Developing assessments
14. What was the strength of the inquiry training?
- Training
 - Planning
 - Implementation
15. What were the weaknesses of inquiry training?
16. How do you suggest changing the inquiry training, if any changes are needed?
17. How do you evaluate the effectiveness of the extended summer science school?
18. Please tell me about yourself
19. Please tell me about yourself
- a. What is your position?
 - b. How long have you been in this position?
 - c. How long have you been in the district?
20. NCLB and Hutton Mufflin have required us to use direct instruction as the primary instructional approach. Problem-based inquiry asks to guide students to do more investigations. Tell us about the instructional strategies that you use to help students explore and investigate?

Appendix B

Classroom Observation Protocol

Summer 2012

Teacher:

Date:

Grade:

Observer:

Number of students in class and gender

of students:

of boys:

of girls:

Description of the classroom (Use the back of the page to draw):

Purpose of the lesson:

Intended outcome:

Checking for prior understanding:

Material used:

Whole-Class Observation

Directions: take notes on the whole class activity and the interaction.

Note taking	Note making

Appendix C

Student Pre-Post Teamwork Survey

Summer 2012

1. When I am in a team, I do my best on my part of the work.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
2. When I am in a team, I ask for help if we need it.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
3. When I am in a team, I turn in my work on or before the due date.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
4. When I am in a team, I do my fair share.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
5. When I am in a team, I help my team to gather information and useful ideas to complete our work.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
6. When I am in a team, I help my team to solve problems.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
7. When I am in a team, I help my team to stay on task.
 - a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
8. When I am in a team, I listen to other members' ideas with respect.
 - a. Always

- b. Most of the time
 - c. Sometimes
 - d. Never
9. When one of my teammates is upset I try to find out why.
- a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
10. When I don't know something, I ask questions.
- a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
11. When I am in a team, I follow team rules (team agreements).
- a. Always
 - b. Most of the time
 - c. Sometimes
 - d. Never
12. The best thing about working in a team is...
13. When I work in a team, the hardest thing for me is...

Gender Grade Level

Appendix D

Summer 2013

Karwan's IDDL Questions to Guide Inquiry Rubric (Cited in Karwan & Nariman, 2014).

TYPES OF KNOWLEDGE	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE		CONCEPTUAL KNOWLEDGE	
TYPES OF QUESTIONS	Questions that get to "Just the Facts"	Questions that Support Skills Necessary to Grasping Concepts		Questions that Support THOUGHT PROBING Questions	
DEPTH OF KNOWLEDGE	Questions that Support Discourse				
	Recall Level 1	Skill Level 2	Strategic Thinking Level 3	Extended Thinking about Content Level 4	Metacognition (Extended Thinking about Own Learning & Thinking)
	• Facts • Definitions • Details • Who, what, where, when • Arrange • Calculate • Illustrate • Identify	• Classify • Predict • Interpret • Show • Make observations • Retrieve information • Compare/Contrast • Determine • Cause and Effect • Identify Patterns	• Justify • Explain • Investigate • Differentiate • Hypothesize • Cite Evidence • Complex Thinking • Abstract Thinking • Assess • Compare	• Apply • Analyze • Prove • Critique • Synthesize • Design • Create • Design	
PROBING TEACHER & STUDENT QUESTION EXAMPLES	What is it? What does it do? What is its function? Is it real or artificial? Is it typical? What is its significance? What is its importance? What is its value?	What would happen if? How might it change over time? What are the expected results? Does it always happen like this? How would you model or draw to show that? What patterns do you see? Can you predict what will happen next?	How can I find out about it? How does it work? How does it happen? What affects it? What does it affect? What is the evidence? What assumptions underlie the evidence? What makes the data/facts accurate? What do others think about what ____ said? Do you agree/disagree? Does anyone have the same idea but a different way to explain it? Can you think of a counter example?	How can this know-ledge be used to solve other problems? What are the future risks, benefits or consequences? What other questions can be asked? How else might we explain what happened? How do you support your position? Can you convince the rest of us your conclusion makes sense? What would happen if...? What if not? How does this relate?	What strategies did you use? How did you think about the task? How did you figure that out? What might you do differently the next time? Why do you think that? How did you reach that conclusion? How could you prove that? What have we learned that helped you to solve this...? Have you ever experienced this before?

Appendix E
Classroom Observation Protocol
Summer 2013

Purpose:

Learning Goals/Intended Learning Outcomes:

Type of Lesson:

Student Centered Group Work:

Engage and Activation Phase--Connection to Prior Knowledge/Preconceptions and Misconceptions:

☐ Student Prior Knowledge/Preconceptions

-
-
-
-

☐ Student Misconceptions challenged by teacher

-
-

☐ Student Generated Questions—Inquiry Prompt

-
-

Explore:

☐ Student Prior Knowledge/Preconceptions

-
-

☐ Student Misconceptions challenged by teacher

-

☐ Student Generated Questions—Inquiry Prompt

-
-
-

Teacher Generated Questions

(can be all three phases in 30 minutes, most likely will see an iteration of both Explore and Explain)

- Engage
 - o
 - o
 - o
- Explore
 - o
 - o
 - o
 - o
- Explain
 - o
 - o
 - o

Check all stages used during the 5e lesson plan:

☐ Engage

☐ Explore

☐ Explain

☐ Extend

☐ Evaluate

Materials used (TO ENGAGE STUDENTS):

TECHNOLOGY:

VIDEOS:

REALIA

Appendix F

Student Focus Group Questions

Summer 2013

1. What have you been studying in your class? What is something exciting (interesting) you learned this week?
2. When I am studying something new, I usually have lots of questions. What questions do you have about _____?
3. Did you have a chance to ask a question this week?
 - a. Do you remember what you asked?
4. Has your teacher been teaching you anything about asking questions?
 - a. What did you learn about questioning?
5. Who asks the most questions in your class, your teacher or other students?
6. What is going on in your head or what are you thinking about when (other student name/teacher) is asking a question?
7. When you don't understand something, is it okay to ask questions in class? Who do you ask? (your teacher? your classmates?)

Metacognition:

1. Do you think that asking your own questions is important?
 - o Why do you think it's important? Why not?
2. What kinds of questions help you learn? (Can you give me an example?)
3. How does asking your own questions help you learn? (Science and/or learn more)

Appendix G

Teachers Focus group Question

Summer 2013

4. What was successful in implementing problem-based inquiry this summer?
5. Over the past three years, how has problem-based inquiry shifted your thinking?
6. How has problem-based inquiry shifted your students' thinking?

Key Questions:

7. This summer a major focus of PD was engaging students in asking/generating questions.
 - o How do you think this focus went?
 - o What sort of scaffolding did you use to help students in generating questions?
 - o How did getting students asking questions affect your instruction?
 - o How did getting students asking questions affect their ownership/engagement in science learning?
 - o How did getting students to ask questions affect their research and investigation skills?
 - o How did students reflect on their questions?
 - o How did student reflections affect their follow up questions?
 - o How did this student reflection impact their learning?
8. What was most difficult in having students generate their own questions:
 - o for you?
 - o for the students?
9. What was most successful in making the shift to students asking the questions:
 - o for you?
 - o for the students?
10. This summer you learned how to plan and implement questioning strategies when students explored and explained their learning. How did your use of questions influence students' questioning?

11. Over the last three years how has Professional Development supported you in your learning of problem based inquiry design?
12. Over the last three years how has coaching supported you in your learning of problem based inquiry design?
13. How would you rate overall the depth of student learning based on the Continuum of Inquiry?
14. Since beginning this journey of implementing problem-based inquiry designs,
 - o What have you implemented in your classroom?
 - o How have you used student teamwork to engage students in problem-solving?
 - o What has been most beneficial for you?
 - o What has been most beneficial for your students?
 - o What has been the most challenging for you?
15. Have we missed anything else that you'd like to add about questioning or problem-based inquiry? (Closing Question)

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