The Development of Interdisciplinary Science Inquiry Curriculum Knowledge

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Abstract

This study is situated in a project called the Interdisciplinary Science and Engineering Partnership (ISEP), a NSF-funded teacher professional development program between 12 public schools and 2 universities in the North Eastern United States. This teacher professional development program affords an opportunity to understanding the processes and conditions in which science teachers develop interdisciplinary science inquiry knowledge and how is that translated into their pedagogical content knowledge (PCK) in such a way that improves student learning. As part of that study and within the framework of pedagogical content knowledge in science, this paper explores development of science teachers' knowledge and practices about curriculums related to interdisciplinary science inquiry. This qualitative study utilizes a descriptive case study approach to understanding how three in-service teachers' curricular goals, in regards to interdisciplinary inquiry, are impacted as they take part in authentic research experiences. Results showed the following: (1) in order to promote teacher "buy-in" and implementation of interdisciplinary science inquiry (ISI), teachers' research experiences must be aligned with their perceived curricular goals; (2) the teachers' understanding of ISI impacted their perceived relevance of the research experience to their curriculum and classroom practices; (3) the Levels of Use spectrum (Hall, Loucks, Rutherford, & Newlove, 1975) is directly connected to how teachers viewed their summer research experience matching their curricular goals; and (4) contextual factors, both cultural and ecological, get in the way of teachers' implementation of doing ISI in the classroom.

Introduction

In the National Science Education Standards (NRC, 1996, 2000), scientific inquiry is viewed not only as content for students to learn, but also an approach to reforming how science is currently being taught. The National Research Council (2012) has released the Next Generation Science Standards that expands upon the concept of developing scientific inquiry to science and engineering practices combined with disciplinary core ideas and crosscutting concepts. This new vision of scientific inquiry may be called interdisciplinary scientific inquiry. With this form of inquiry, while maintaining the distinctness of traditional disciplines, the lines between the branches of science, engineering, and technology are blurred as students are asked to solve meaningful, everyday problems.

> Interdisciplinary science inquiry (ISI) is a mode of inquiry that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (NAS, 2004)

The emphasis of ISI in the next generation science standards represents a conceptual shift on how science should be taught within schools in the United States in the future (NRC, 2011). In order for this new form of inquiry to be successfully implemented into classrooms, teachers must not only be aware of the skills and mindsets necessary to conduct it, but also in how it translates to the lives and needs of their students.

While the NGSS is still in the development stage, with the final draft scheduled for release in the spring of 2013, teachers in the United States are currently facing the implementation of another new set of standards. The National Common Core Curriculum Standards (NCCC) were released in 2010 and introduced to teachers during the 2011-2012 school year. These standards were developed in response to the reported lack of college readiness amongst students upon graduation from high school (Porter, McMaken, Hwang, & Yang, 2011). In today's global community, it is commonly accepted that in order for students to compete and be successful in the job market they must go to college (Hill, 2011). The NCCC is currently divided into two major categories: Mathematics and ELA. The later group encompasses the development of literacy in not only English classes, but in history and social studies, science, and other "technological subjects". The implementation of these standards into science classrooms are currently designed to act as a supplement to content standards in such a way that students develop expertise in reading, writing, speaking, listening, and language within the field of science (Common Core State Standards Initiative: Introduction). The expectation of NCCC on ISI is consistent with that of NGSS.

According to Bybee and Ben-Zvi (2003), when changes are made to the science curriculum, teachers may need to change the ways in which they teach science. While the federal government and state and local education departments can create new curriculums and implement new standards for education and teaching, it is the teachers who make the final decision about how to use that new curriculum in their classrooms. Van den Akker (2003) states "the most fundamental problem might be that these kinds of reforms require significant changes in teachers' values and beliefs about appropriate science education practices and their own role in that practice" (p. 441). Thus, finding out current science teachers' beliefs and values of ISI in the new and upcoming curriculums, i.e., the common core and the next generation science standards, is both theoretically and practically significant in science education research.

This study is situated in a project called the Interdisciplinary Science and Engineering Partnership (ISEP), a NSF-funded teacher professional development program between 12 public schools and 2 universities in the North Eastern United States. One main purpose of ISEP is to improve science teachers' content knowledge and skills in conducting interdisciplinary science inquiry through conducting research at the university in the summer and engaging in ongoing professional development during the academic year. This teacher professional development program affords an opportunity to understanding the processes and conditions in which science teachers develop interdisciplinary science inquiry knowledge and how is that translated into their pedagogical content knowledge (PCK) in such a way that improves student learning. As part of that study and within the framework of pedagogical content knowledge in science, this paper explores development of science teachers' knowledge and practices about curriculums related to interdisciplinary science inquiry.

"Teachers' understanding of curriculum materials, their beliefs about what is important, and their beliefs about the roles of the students and the teachers all strongly shape their practice" (Coenders et al., 2008, p. 332). The investigation of science teachers' knowledge of interdisciplinary science inquiry as its related to their curriculum will hopefully provide insight into the underlying factors that impact the implementation of new curriculum and ideas. As standard-based reform within the United States continues on its path of developing standards for improved scientific and interdisciplinary scientific inquiry in science classrooms across the nation, the value of understanding how teachers perceive and enact these new standards for learning is in the success of these new reforms on impacting student science achievement.

Literature Review

Impact of Research Experience for Teachers

One of the professed goals of the Interdisciplinary Science and Engineering Partnership (ISEP) is to improve middle and high school science teachers' knowledge and skills related to STEM areas of research through the engagement of these teachers in interdisciplinary science research and engineering design with university STEM faculty. The desired outcomes of this goal include that the participating science teachers will demonstrate advanced knowledge and skills in conducting scientific research and design, have an improved understanding of science and inquiry science teaching, and improved practice in conducting inquiry science teaching.

Both the goal and outcomes of the intervention mirror past research that has been done on the impact of providing science teachers with research experience (Dresdner & Worley, 2006; Lord & Peard, 1995; Pegg, Schmoock, & Gummer, 2010; Pop, Dixon, & Grove, 2010; Yerrick, Parke, & Nugent, 1997). For example, Dresdner and Worley (2006) investigated the impact the Woods (TIW) program had on practicing science teachers. The researchers found that the involvement in the program led to improved teacher capacity to provide field experiences for their students, strengthened teacher confidence, and contributed to a significant change in ways participating teachers taught.

Teachers left the research experience with a greater repertoire of teaching practices. Dresdner and Worley (2006) state:

> Engaging teachers in real-world science research is an effective way for teachers, and consequently, their students, to learn ecological knowledge and skills. This experience can lead to science teaching for greater conceptual understanding and increased motivation on the part of the students. (p. 12)

Similar to the TIW program, the NSF's Research Experiences for Teachers (RET) program provides teachers with the opportunity to develop and expand upon their real-world research strategies through the placement of those teachers in research laboratories. Based on the cognitive apprenticeship model, the RET program allows "teachers play the role of the student in the learning process in order to acquire the skills and knowledge relevant to the practice of science" (Pop et al., 2010, p. 129). The survey results of the study done by Pop et al. (2010) found that even though almost half of the teachers who participated in the RET program applied more real-life situations to their teaching activities and more than a quarter were more confident about teaching science, there was not an overall and immediate implementation of RET practices by the majority of participating teachers. These findings led the researchers to suggest that future research should focus not only on what the immersion programs offer in terms of laboratory and research experience for teachers, but what happens when teachers return to their classrooms.

Lord and Peard (1995) found that both science researchers and science education researchers have an impact on science teachers' attitudes towards science. In this particular study, science teachers in Philadelphia spent 3 weeks at a university where they spent time with practicing scientists in fields of physical, biological, and geological science during the day and then met with science educators in the evening to discuss pedagogical and practical applications of what they had learned during the day. Their findings support the concept that in order for teachers to change, they must gain not only the skills of inquiry in the context of doing inquiry, but also the knowledge of how to integrate those skills within their classrooms and have the proper support system in place to facilitate the desired changes.

PCK and Curriculum Knowledge

"A teachers' knowledge base consists of academic knowledge, pedagogical content knowledge (PCK), and experiential knowledge" (Coenders, Terlouw, & Dijkstra , 2008, p. 319). Pedagogical content knowledge (PCK) was defined by Shulman (1986) as "subject matter knowledge for teaching" and as "the ways of representing and formulating a subject that make it comprehensible to others" (p.9). Academic knowledge comes from a teacher's understanding of science content, the nature of science, as well as his or her understanding of how students learn. Shulman described pedagogical content knowledge, or PCK, as an understanding of teachers' knowledge about their subject matter, about how to teach it, about how students learn best, and about how to organize and present the content in ways to promote student learning (Barnett & Hodson, 2001; Bransford et al, 2000; Bybee, 2002; Duschl, Schweingruber, & Shouse, 2007; Loughran, Mulhall, & Berry, 2004; Mansour, Halim, & Osman, 2010; Shulman; 1986; van Dijk & Kattmann, 2007; Van Driel, Beijaard, & Verloop, 2001). Experiential knowledge is knowledge about teaching and learning that develops through experience and is often implicit or tacit (Coenders et al., 2008). "Teachers' understanding of how students learn has important implications for how they structure learning experiences and make instructional decisions over time" (Duschl et al., 2007, p. 301).

Pedagogical content knowledge also includes a teacher's understanding of how to help students understand a specific subject matter. This entails knowledge of how particular topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction (Magnusson, Krajcik, & Borko, 1999). Curriculum knowledge is a component of pedagogical content knowledge and includes knowledge of mandated goals and objectives, articulation of guidelines, and knowledge of vertical curriculum within the subject (Magnusson et al., 1999). Curriculum knowledge is defined as

> the ability to apply theoretical principles and behavior associated with planning, implementing, and evaluating curriculum, (Behar, 1994) in differentiating instructions (Joyce, Weil, & Showers, 1993), and in enhancing the capacity for responsiveness to the social context and dynamics of student classroom milieu. (Behar & George, 1994, p. 48)

Magnusson et al. (1999) describes two types of science curriculum knowledge: (a) knowledge of mandated goals and objectives (e.g. state and national standards) and (b) knowledge of specific curriculum programs and materials. When it comes to the impact of teachers' knowledge of curriculum, Abell (2007) cited a 17-year longitudinal study on science teachers done by Arzi and White who determined that the required science curriculum had the greatest impact on the knowledge base of teachers.

In the era of standards-based reform, researchers and policy makers alike must analyze how the standards play into teachers' PCKs, as this could potentially be the most important aspect in whether or not those standards succeed. According to van den Akker (2003) "new curriculum ideas will not affect classroom processes until teachers have had sufficient opportunity and support to internalize the teaching repertoire, particularly beliefs associated with those actions" (p. 443). In order for them to be meaningful and to make permanent changes in classroom practices, one must take into account the beliefs of teachers as the implementation of new curriculums and ideas often requires teachers to transform or adapt their understandings of teaching and learning (Powell & Anderson, 2002).

Teacher Beliefs

Of the research that has been conducted on implementing new standards into the classroom, it has been identified that teachers' beliefs play an important role into their successful integration. While national and state education boards have adopted these new standards for student learning, numerous studies have shown that both the success and enactment of standards ultimately comes down to the perceptions and actions of teachers (Coenders et al., 2008; Cronin-Jones, 1991; Harnack, 1968; Metty, 2010; Tobin & McRobbie, 1996; Yerrick, Parke, & Nugent, 1997). The instructional and curricular decisions made by teachers determine the content taught, the amount of time required to teach that content, the types of teaching strategies implemented, the set goals and objectives, as well as determining what to assess and the desired assessment formats (Harnack, 1968). Underlying these decisions are teachers' personal beliefs about their subject matter, how to teach, how to assess students, and the required mandates of the new standards/curriculum being put into place. Beliefs are considered to be personal constructs of a teacher's practice and have been connected to both the planning and enactment of instructional practices in the classroom (Roehrig & Kruse, 2005). According to Coenders et al. (2008), beliefs act like a filter through which new knowledge is interpreted and implemented.

"People's beliefs are powerful motivation agents" (Coenders et al., 2008, p. 332). Teachers' beliefs about teaching and learning develop from their personal and professional experiences and affect the decision-making, planning, and execution of the activities and content chosen. Mansour (2009) states that "beliefs become personal pedagogies or theories to guide teachers' practices: teachers' beliefs play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks" (pg. 31). These personal pedagogies are played out in the day-to-day decisions that teachers make concerning what to teach, what to skip, and how much time and attention will be given to certain topics of study (Cronin-Jones, 1991). Teachers, who share similar academic knowledge, may not necessarily teach the content in similar ways. It has been shown that teachers' beliefs are more influential than their knowledge in determining the way in which they teach (Mansour, 2009).

Teachers tend to adapt a new curriculum during its implementation according to their own beliefs (Vos et al., 2011). These adaptations are in part determined by whether or not the new curriculum is perceived to support or threaten teachers' beliefs. "Teachers do not implement curriculum materials that contradicted their ideas about content and how this content should be taught" (Coenders et al., 2008, p. 320). The decisions made by teachers concerning what to include or what to omit threaten the integrity of the new curriculum or standards being implemented within schools. The consequence of ignoring the influence of teachers' instructional decisions has been well documented in literature (Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996; Haney, Lumpe, Czerniak, & Egan, 2002) and must be accounted for when changes to the science education curriculum are being made. Understanding of the perceptions, beliefs, and knowledge held by teachers could serve to explain the variance seen in how teachers respond to and enact new curriculum and standards.

Contextual Factors

Contextual factors also play a role in influencing the actual practices of teachers. While teachers can learn new skills and teaching practices through the engagement in professional development programs, there are often factors within the school and classroom that impede their implementation of those skills and practices they have learned. According to Deci and Ryan (2000), "context affects learners in their choice of performing a certain task and the degree to which learners have control in this process" (cited in Pop et al., 2010, p. 130). Hall and Hord (2001) define contextual factors as being comprised of culture and ecological factors. Culture consists of the "individually and socially constructed values, norms, and beliefs about an organization" (p. 194). Ecological factors are situational factors that include resources available, budgets for supplies and materials, school policies, and personnel issues.

Teachers' beliefs regarding their knowledge, curriculum, and students' ability have been shown to factors that influence their pedagogical decisions. In a study done by Gilbert and Yerrick (2001), the teacher's perception of how he viewed his students' ability to do science influenced how he taught science. The deficit lens with which he viewed his students severely limited the types of lessons he thought they would be able to successfully complete. As a result, his classroom practices were centered on learning basic scientific knowledge through the use of the textbook and "easy-to-follow directions and discrete packages of information relating to facts and proven theories included in the state-mandated earth science curriculum" (p. 585).

In a study that looked at how teachers' gained practical knowledge and skills related to inquiry-based curriculum implementation, Jones and Eick (2007) found that classroom management and limited knowledge of how to confront students' preconceptions as obstacles to implementing inquiry. In this study, the researchers followed the two teachers highlighted through the process of implementing Science and Technology for Children (STC) and Science and Technology Concepts for Middle School (STC-MS). Their findings indicated that even though the teachers reacted positively towards the curriculum, there were several factors that have a negative impact during the implementation process. Those factors included the management of materials and time. Managing materials required to do inquiry in the classroom can lead to additional issues of classroom management for teachers, when compared to more traditional styles of teaching. In regards to time, planning for and implementing inquiry in the classroom takes more time than other forms of instruction and can lead to frustration. However, the researchers found that with additional use and support, the teachers in the study were able to more successfully implement aspects of the inquiry-based curriculum. These findings highlight the assumption that in order to better understand why teachers may or may not be implementing interdisciplinary science inquiry into their classroom practice, the contextual factors that get in the way of implementation need to be identified and addressed.

Theoretical Framework

The theoretical framework that guides this study is pedagogical content knowledge as it relates to curriculum knowledge. The definition of curriculum knowledge that was utilized by this study follows that of Behar and George (1994), in which curriculum knowledge is seen as

> is the ability to apply theoretical principles and behavior associated with planning, implementing, and evaluating curriculum, in differentiating instructions, and in enhancing the capacity for responsiveness to the social context and dynamics of student classroom milieu. (p. 48)

As there is currently no direct measure of interdisciplinary science inquiry curriculum knowledge, the theoretical construct utilized by this study is the *Levels of Use of the Innovation* (LoU) scale, which is one of three components of the *Concerns-Based Adoption Model* (CBAM) (Hall, Loucks, Rutherford, & Newlove, 1975). The Level of Use concept goes beyond asking whether or not a teacher is using an innovation by identifying the level at which that teacher is using or not using that innovation. According to Hall et al. (1975),

> "Change" or innovation adoption is not accomplished in fact just because a decision maker has announced it. Instead, the various members of a user system,

> such as teachers and professors, demonstrate a wide variation in the type and degree of their use of an innovation. (p. 52)

The process of innovation implementation is just that a process. Individuals who participate in the implementation process do so at varying levels of involvement. Hall et al. (1975) make the assumption that in order for an innovation to reach its highest level of effectiveness, the variations observed amongst individuals must be described and accounted for.

The Level of Use concept describes eight discrete levels of innovation use. These levels of use include three levels of varying nonuse and five levels of use. Each of the levels is further defined by seven categories: knowledge, acquiring information, sharing, assessing, planning, status reporting, and performing. Table 1 describes the eight levels of use (Hall et al., 1975, p. 54).

(Insert Table 1 About Here)

Hall and Hord (2001) define an innovation as a program or process being implemented. The innovation can be a specific product, such as a new textbook or curriculum, or a process, such as incorporating a different approach to a concept or different instructional practices. In the case of this study, the innovation is interdisciplinary science inquiry as both content and pedagogy. According to Nargund-Joshi, Liu, Chowdhary, Grant, and Smith (2013, April), ISI consists of four dimensions: (1) Science and Engineering Practices, (2) Crosscutting Concepts, (3) Disciplinary Core Ideas, and (4) Drivers of Interdisciplinary Research. This four-dimensional framework is informed by nature of interdisciplinary science inquiry (NRC, 2004), the next generation of science standards (NRC, 2012), and integrated science (Czerniak et al., 1999); it guides the project implementation and evaluation.

The innovation of interdisciplinary science inquiry is based upon the following premises: (1) anchoring instruction and content within the discipline being taught, (2) creating connections within and across disciplines, (3) incorporating inquiry process skills and practices, and (4) asking meaningful and authentic questions. Understanding teachers' levels of use in terms of their knowledge and implementation of aspects of ISI are a valuable and preliminary step in determining further courses of action that can be taken to promote their use of this innovation. According to Hall and Hord (2001), "levels of use, or how teachers are using an innovation, is specific input for the facilitator in determining how to help teachers become increasingly successful and effective in using the innovation" (p. 14). Given the need to understand how teachers interpret their summer research experiences in regards to their curriculum plans and actual practice as well as the specific factors that impeded the implementation of their experiences, the following questions guided this present study.

1. To what extent and in what ways does the summer research experience influence science teachers' beliefs and decisions about curricular goals?
2. To what extent and in what ways are these curricular goals enacted upon in their actual classroom practices?
3. What contextual factors impede the enactment of teachers' goals in their classroom practices?

Design of Study

This qualitative study utilizes a descriptive case study approach to understanding how in-service teachers' curricular goals, in regards to interdisciplinary inquiry, are impacted as they take part in authentic research experiences. Yin (1994) describes a case study approach as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p.13). As a result of using this approach, a deeper understanding of "why" and "how" the summer research experiences impacted teachers' pedagogical content knowledge as it relates to their curricular goals and practices could be divulged.

Context and Participants

The participants in the study comprised a total of 58 in-service teachers who currently teach in a public middle or high school in a large city in eastern United States. These teachers took part in a summer research experiences with different scientists who are actively doing research in a wide variety of science, engineering, and computer science fields. The partnership, funded by NSF, between two universities and 12 public schools was designed to enhance the experiences of students in science, engineering, and technology. The twelve participating schools are identified as high-needs schools and consist of 7 high schools and 5 middle or elementary schools that are feeder schools for those high schools. Through teacher professional development opportunities such as the summer interdisciplinary science and engineering research experiences in laboratories across the city, one of the focuses of the partnership was to enhance the participating teachers' pedagogical content knowledge and science inquiry knowledge and skills. Ultimately, this enhanced understanding and knowledge of science and inquiry, particularly interdisciplinary science inquiry, will lead to improved student learning in science.

Purposeful sampling of the participating teachers was done to illustrate not only the wide spectrum of experiences the summer research project offered, but also the range with which teachers fall on the Levels of Use spectrum. The three cases selected were chosen and organized based on the evolving nature of Levels of Use from non-user to user. Pseudonyms were used to protect the teachers highlighted in the study.

Ms. Lewis is a white, female high school science teacher. She has been teaching for 5 years and has been at her current placement for 3 years. At the time of the study, she taught forensic science, environmental science, and Living Environment to students in grades 9 through 12. Ms. Lewis teaches at West High School, one of seven participating high schools in the study. More detailed demographics for West High School are provided in Table 2.

Mr. Brown is a white, male high school science teacher who has been teaching for 11 years and is currently teaching at Central High School. He teaches 9th grade Living Environment, environmental science, and an environmental science course to students in grades 10 through 12. He also runs the schools Aquaponics club. The high school that Mr. Brown teaches at has almost one thousand students in grades 9-12 and is considered to be a high-needs school. More detailed demographics for Central High School are provided in Table 2.

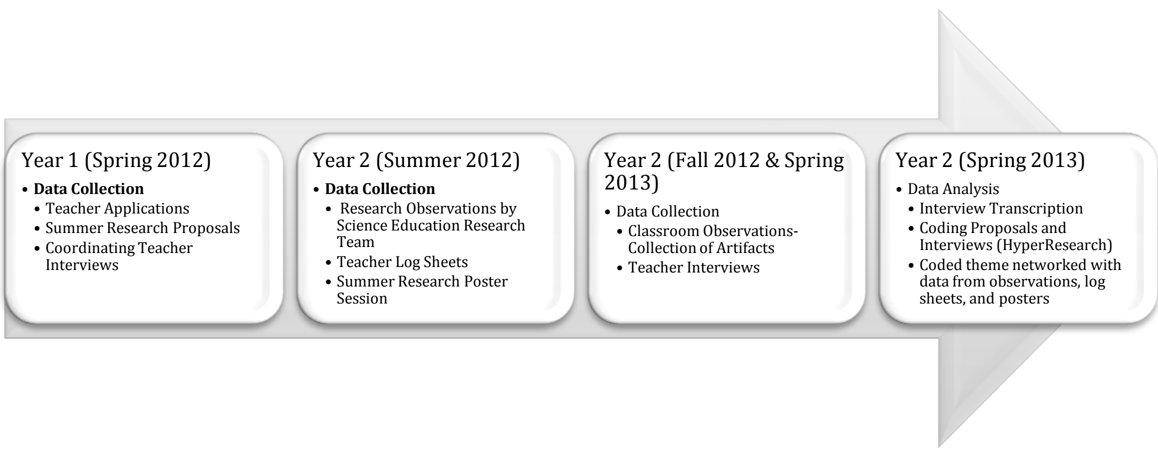
The third teacher highlighted in this study is Mrs. Williams. Mrs. Williams has been teaching science for 43 years, with 31 years at North Park Elementary School. She teaches middle school science and Living Environment to 7th and 8th grade students at one of the five participating elementary schools. North Park Elementary School serves almost 1000 students and, unlike the high schools highlighted in this study, is considered to be one of the highest performing elementary schools in the district. 70% of students who attend receive free lunch. More detailed demographics for North Park Elementary School are provided in Table 2.

(Insert Table 2 About Here)

Data Collection and Analysis

Data Collection

To investigate the personal viewpoints of the participating teachers' summer research experiences on developing an understanding of interdisciplinary inquiry and how those experiences and knowledge influenced their curricular goals and classroom practices, multiple sources of data were collected and analyzed. Data was collected in three waves. The timeline below illustrated the data collection and analysis process for year 2 of the ISEP grant.



The first wave of data collection consisted of the teachers' summer research proposals. The participating teachers submitted a written proposal for review the spring prior to their research experience. These proposals asked teachers to share the following information: subject/course teaching, school, school science theme, proposed research concept, implementation plan, current understanding of interdisciplinary science inquiry in middle and secondary school science, perceived challenges of conducting ISI within the classroom, their proposed research concept, experience, or coursework, and how the proposed plan will benefit their teaching.

The second wave of data collection occurred during the teachers' summer research experience. The data included teachers' log sheets, researchers' observation notes and videos, and data from the teachers' poster presentations. These forms of data were purposefully selected to assist in understanding the individual experiences of participating teachers and how those experiences influenced their developing curricular knowledge of inquiry, particularly interdisciplinary science inquiry. The log sheets asked teachers to rate how their daily or weekly experiences in research aligned with aspects of interdisciplinary science inquiry, particularly science and engineering practices and crosscutting concepts, and how they could be translated into their classroom practices. The observations that were recorded included: small group discussions between researchers and teachers; laboratory sessions and hands-on experience with equipment and techniques of data collection, such as using Probe ware to test water samples and running gel electrophoresis on different samples to identify relationships or presence of certain markers within those samples; and field work where samples, such as the water samples tested in the lab, were collected. At the culmination of the summer research experience, teachers constructed a poster presenting their overall summer research experience while also explaining how their experience could be translated into their classroom practice. These posters not only highlighted the variety and range of teacher research experiences, but also illustrated the many ways in which they saw these experiences being translated into their middle and high school classrooms. Through this, their interpretation of how summer research experiences connected with specific aspects of their school curriculum in regards to content and planning were either detailed or could be inferred from their conclusions (Behar & George, 1994; Magnusson et al., 1999).

The third wave of data collection occurred during the school year following the summer research experience. Semi-structured interviews were conducted to discern how the teachers saw their experiences aligning with the interdisciplinary science inquiry framework and with their curriculum. These interviews took between 45 and 90 minutes. The semi-structured format was used to allow the teachers to narrate their own interpretations of their summer research experience, interdisciplinary science inquiry, and how both were put into planning and practice in their classrooms. The interview questions fell into the following general categories: personal teaching history and style, summer research experiences, utilization of summer research in planning, utilization of summer research in teaching, understanding of interdisciplinary science inquiry and how to incorporate it planning, practice, and assessment, role of research mentor and university STEM students, and their personal perceptions of the ISEP project as it relates to their students, schools, and the partnership between the schools and universities involved. Also, over the course of the school year, classroom observations were done to evaluate the teachers' implementation of interdisciplinary inquiry activities they designed. A standard protocol was used to ensure the validity and reliability of observation techniques and identification of aspects of interdisciplinary science inquiry.

Data Analysis

Data were analyzed using an inductive approach (Patton, 2002). Data analysis was completed on all sources of data by multiple researchers to ensure that the findings and emerging themes were valid. The four dimensions of the ISI framework guided the analysis of the participating teachers' knowledge and conceptions of their summer research experiences in regards to their curriculum knowledge and enactment.

Upon examining a subset of the interview transcripts, coding keywords were identified in the following categories: personal background, why teach science, what want students to learn, summer research experience, goals prior to and after summer research experience, teacher knowledge of the ISI framework, teacher beliefs concerning how to use ISI in classroom, enactment of ISI framework and summer research in the classroom, role of research mentor and STEM students, and overarching purpose of ISEP project. All of the compiled teacher interview transcripts and research proposals were then coded using HyperResearch.

The process of constant-comparative analysis was utilized to understand teachers' personal interpretations of their research experiences as well as the potential and actual implementation aspects of each dimension of ISI in their classroom practices (Patton, 2002). From analysis of the codes of the transcripts and proposals, themes emerged. The code themes centered on: summer research experience and goals, knowledge and use of ISI in the classroom, and the contextual factors that the teachers felt limited their ability to implement their summer research and ISI. The analysis process continued with the examination of log sheets, field notes and videos of curricular activities, as well as artifacts such as the teachers' research posters and classroom lessons to develop a more detailed description of the teacher's experiences, goals, and levels of ISI use in their classroom.

Cases were generated for each of the teachers and using the codes and themes generated, additional information from the researchers' observations of the teachers' summer research experiences, the teachers' summer research log sheets and posters, and classroom observations were added to each case to enhance the researchers' understanding of what the teachers experienced during the summer and how that did or did not impact their actual practice. Case results were then organized based on Hall et al.'s (1975) Level of Use scale. As mentioned previously, the three teachers highlighted in this study were selected based on the their representation of the wide spectrum of teacher use and non-use of the summer research experience and interdisciplinary science inquiry. Based on the case descriptions, claims were created to explain the variation among the cases.

Findings

Case 1: Ms. Lewis

Ms. Lewis, who was trained in forensic chemistry during her undergraduate study, applied to the ISEP program with the expressed desire to do research in a field that was forensic-related. Given her background and training in forensics, Ms. Lewis was placed in an analytical chemistry lab under Dr. Black, whose research focus is materials science and engineering. Prior to her summer research experience, Ms. Lewis stated that her goal was to gain new knowledge so that she could translate that into creating new hands-on and engaging activities for her students. As a result of the research experience, Ms. Lewis stated that she wished to make her forensic science classes more fun, in the hopes that this would improve student attendance and motivate students to come to class.

> The student performance at West High School is generally below average, mainly due to low attendance. I hope that the lessons and ideas I gain through this experience will motivate them and help them to understand that school can be fun. Many students claim the reason for their poor attendance is lack of interest in what is happening in the classroom. If I can make it engaging and exciting I am hoping that this will higher students' interest levels therefore improving

> attendance rates. If they are here, we can teach them, which will improve overall performance. (Source: Summer Research Proposal)

The desire to make her classes fun and interesting for students is directly related to how Ms. Lewis views teaching, particularly teaching forensic science. When asked to explain what her purpose for teaching science was, Ms. Lewis responded by stating:

> What is my purpose? Well, I mean it is almost like a selfish thing because I feel like I get enjoyment out of teaching it. Like forensics is just fun for me. I mean it is fun for them too, but like it's fun for me so I don't get bored. My purpose specifically for me for science is just cause it is enjoyable for me. I like the kids to learn about stuff that they like. They don't really think its science. I mean, there is benefit for them too, but its fun for me. To be honest.

During the four weeks that Ms. Lewis spent in the lab, she analyzed textile fibers using epiluminescence microscopy coupled with CRI Nuance EX. Using 24 different denim fiber samples, Ms. Lewis, with the aid of graduate students in Dr. Black's laboratory, collected fiber fluorescence imaging data and found that while this technique is useful in discriminating between bull denim fibers, additional testing would be necessary to discriminate between indigo-dyed blue fibers.

At the end of Ms. Lewis's research experience, her proposed goal was to improve her hair and fiber unit. In years prior, Ms. Lewis taught hair and fiber analysis through visual analysis of different samples and burn tests. On her summer research poster, Ms. Lewis professed that as a result of the project, she planned to illustrate to her students how sprectochemical imaging, the focus of her research, can be as an additional method of fiber analysis. However, when interviewed in the fall, Ms. Lewis stated that while overall the research experience was interesting, she used equipment and techniques that are difficult to translate back to her classroom:

> It was a little different than what I expected because I was based in the chemistry department where as I am not used to that because I don't do anything with chemistry, really. Um, and we kind of researched fiber and the way different fiber reacts to light and stuff like that. It was basically using machines and things like that that I have never used before. It was interesting, but I don't know that I can apply a lot of the stuff that I did because I don't really focus on fiber in forensics for more than 3 days. (…) It was useful for me because it was different and was something for me to see how forensics could really work in real life. I can share it with my kids as something that I did, but it is not like something I can have them actually, physically do.

Level of Use – What does the Summer Research Experience and Curriculum Goals look like in Practice?

Ms. Lewis's description of her summer research experience, particularly her statement regarding student use of the techniques she learned over the summer, was an initial indicator as to where she fell on the Levels of Use spectrum in regards to her understanding of interdisciplinary science inquiry and the implementation of both ISI and her summer research experience in her classroom. Upon further evaluation of Ms. Lewis's implementation, or lack thereof, of the ISI framework and summer research experience it was determined that she exhibits the behaviors of a nonuser of the ISI innovation. According to Hall and Hord (2001), a nonuse individual is one who "knows very little or nothing at all about an innovation or change, and exhibits no behavior related to it" (p. 83). Of the seven dimensions that comprise the LoU instrument, Ms. Lewis was keyed out to be at nonuse for all of them.

Knowledge of Interdisciplinary Science Inquiry

Overall, Ms. Lewis has limited to no knowledge of the key aspects of ISI, which include not only the science and engineering practices, crosscutting concepts, disciplinary core ideas, and drivers of interdisciplinary research, but also how her summer research experience exemplified any of those dimensions. Ms. Lewis stated that interdisciplinary science inquiry involves:

> Well to me it is more or less taking things, taking other subject areas and putting it into the curriculum that I have, like with math, reading, writing, and English and pulling all of that stuff in. Inquiry based? I don't know how. I mean a lot of stuff that I do is not entirely inquiry-based, it's a lot of very guided. It's kind of hard to just say, you know are doing this blood lab, here you go. A lot of this stuff just has to be guided with the tools that I give them. The stuff that I give them is like… There's not a whole ton of inquiry in it.

As evidenced in the statement above, to Ms. Lewis interdisciplinary science inquiry involves incorporating math and English Language Arts (ELA) into her curriculum. In referring back to the four dimensions of the ISI innovation, there is no mention of designing her curriculum in such a way that introduces students to authentic problems that are grounded in the discipline or other disciplines within the fields of science and engineering. Ms. Lewis also fails to describe what it means to conduct inquiry by stating that she simply does not do a lot of inquiry in her classes. When probed for a deeper understanding regarding the different aspects of ISI, Ms. Lewis further acknowledges her lack of knowledge in those areas.

> Int: Do you know what crosscutting concepts are?
> Ms. Lewis: No.
> Int: Well, crosscutting concepts are things like identifying patterns, cause-and-effect, structure and function. There is a size and quantity measurement. When we think of crosscutting we think of concepts that can carry between disciplines, so that is kind of what crosscutting concept is. Are there any ones that I just mentioned that you currently see in your classroom that you use?
> Ms. Lewis: Well, not in forensics. I don't know that we do that kind of stuff.
> Int: Another part of this framework integrating engineering and technology. Do you feel you could implement engineering into your teaching?
> Ms. Lewis: I don't know what that would mean.
> Int: What do you think you might need to learn to implement engineering practices?
> Ms. Lewis: I mean I don't know how I would do it. I don't really know what I

> would even need to do that because I don't know what you would design a model of in forensics. I don't know what you would do because I feel like most of the stuff has already been kind of set up. I don't know that you would design anything.

The limited understanding that Ms. Lewis exhibits in regards to knowledge of practices and crosscutting concepts, and how to implement technology and engineering into her classroom practices in turn limits her ability to construct experiences for her students that incorporate these elements of ISI. Her experiences in the research laboratory resulted in her gaining knowledge of a new research technique and not necessarily the underlying premises of what science looks like in today's society. Furthermore, her acknowledged lack of how to do more than is already set up for her is indicative of how she perceives her job of disseminating information to students rather than creating an inquiry-based learning environment where students have the opportunity to pose their own questions and develop solutions to those questions.

Acquiring Information

The second category of LoU is acquiring information about the innovation. Over the course of this study, Ms. Lewis has not taken any deliberate actions to learn more about how to implement her summer research experiences into her classroom nor on what interdisciplinary science inquiry is and how it might look in the classroom. She has not attended any of the monthly professional development sessions offered by the science education researchers involved in the program and acknowledges that she is not making use of the STEM graduate and undergraduate students that have been placed in her school.

Sharing and Assessing

Exhibiting further signs of being at the level of nonuse, in addition to not acquiring additional information, Ms. Lewis is also not communicating with others involved in the program. This is again evidenced through her lack of attendance at monthly professional development sessions and limited electronic correspondence with science education research team. Ms. Lewis is not taking any actions to analyze how to implement her summer research experience into her classroom. This can be seen in her lack of use of her summer research experience as seen in her not teaching fiber analysis to her students. Which is in turn tied to her plan at the time of the study to drop that particular unit from her curriculum for the year. As mentioned previously in Ms. Lewis' description of her summer experience, she explains her rationale for not implementing her research experience as that experience, in her opinion, only related to a topic she covers for 3 days during the school year and therefore was as applicable to her curriculum as a research experience focused in a biology-related would have been.

Planning, Status Reporting, and Performing

In regards to planning, an individual who exhibits of the behavior of nonuse does not show evidence of scheduling a time to use or steps involved in using the innovation being investigated. Ms. Lewis's expressed curriculum goal, prior to starting the study, was to create a laboratory experience for her students that involved the techniques she learned over through the summer research experience. However, when asked after the summer experience how she is using her summer research in her planning, Ms. Lewis openly acknowledges that at the time was not using any of her summer research experiences, nor did she plan to during the remainder of the school year.

> Int: How are you currently utilizing your summer research experiences in your planning?
> Ms. Lewis: Um, I'm not. I'm not going to lie.
> Int: How are you planning to modify your summer experience to fit into your school curriculum? Or are you planning to?
> K: well… I don't know that I'm going to incorporate. I think this year it's tough because I'm leaving in February, so I'm trying to crunch a lot of stuff in all at once so I can give them the good stuff when I'm here and let them have the experience when I'm here as opposed to what they're going to do when I'm gone, when I'm just got a tell the sub to cover some things. So I didn't even do fiber this year. I usually go fingerprints, hair, fiber, blood. I skipped hair and fiber and went right to blood. It's just kind of how it has to be this year and so I'm not, I'm not even planning on covering fiber.

The research experience that Ms. Lewis had was not in her specific area of interest and as a result of her lack of interest, she did not see her students having any interest in it either.

Contextual Factors that Limit ISI Implementation

As stated previously, that while teachers, like Ms. Lewis, can be given the opportunity to learn new skills and techniques through their involvement in professional development programs, often times there are factors that get in the way of them putting those newly learned skills into actual practice. For Ms. Lewis, those factors ranged from the time she would be missing during the school year due to a medical leave to her limited knowledge of the equipment and ideas she learned over the summer and her views of her students' capabilities.

Ms. Lewis's perception that the experiences she had over the summer were beyond the capabilities of her students is directly connected with the struggles she faced to understand the techniques and equipment being used in the laboratory.

> Int: Why do you think it is maybe a challenge or it doesn't match as well to implementing your summer research into your classroom? What is the biggest challenge or challenges you see with translating it into practice?
> Ms. Lewis: Well because with these kids, it's so way over their heads. It's so advanced. It is stuff that I could barely explain and understand at times that I don't see how I could take it and explain it to them and let them do the things that are related to it if I'm not 100% confident in everything. Even when we would like to explain what we did I would always have Randy, the graduate student, talk about the microscope because I couldn't remember everything about this microscope. You know, she would tell me 10 times and her expertise is just not mine. If I don't feel completely comfortable with everything about it, I don't want to bring it to them (the students).

The perceived lack of connection between the summer research experience and her forensic science curriculum resulted in Ms. Lewis' decision to not implement any aspects of that experience into her classroom practices. Learning a new research technique with equipment that she felt was beyond the scope of her students' abilities contributed to this decision. As a result, Ms. Lewis was classified as a nonuser of the ISI innovation. Contrary to this, the cases that follow illustrate participating teachers who were capable of connecting their summer research experiences to their curriculum and classroom practices. Even though each case is unique in regards to how ISI is perceived and implemented within the curriculum, the teachers were able move beyond the level of nonuser and into that of a user.

Case II – Mr. Brown

Mr. Brown considers himself to be a nontraditional teacher as he was certified under the No Child Left Behind Act. His background, prior to teaching, is in criminal justice with an emphasis towards environmental science. His summer research proposal was to create an aquaponics model in his classroom. Aquaponics is the merging of hydroponics and aquaculture. The model would represent a sustainable system and be used to illustrate how both vegetables and fish can be grown as potential food sources. Mr. Brown proposed that this would enhance how he has been using the SEPUP Science and Global Issue curriculum by providing students with an actual model of a sustainable ecosystem and the chance to be involved in the inquiry process. In Mr. Brown's summer research proposal, he justifies the creation of this model by writing:

> One of the challenges that students face when forming constructive response questions on a Regent's exam and in the future on Common Core assessments is the lack any form of natural science experience. A result of this lack of educational experience, students have difficulty writing about environmental situations, food webs, interrelationships between species and real solutions to sustainability challenges. This model will give students hands on inquiry-based experience.

Given Mr. Brown's background in environmental science and proposal for research, he was placed in the environmental science cohort under the direction of Dr. Grant. Dr. Grant has a background in quantitative analysis, surface chemistry, and environmental chemistry. Mr. Brown's research experience within this cohort was split in four different segments. While he spent time on the university campus working in a chemistry laboratory learning about how to use Probe ware to analyze water quality, the remainder of the summer research time was spent on his own researching and creating the aquaponics system for his classroom. He summarizes his research experience by stating:

> I did four different things. I went to the university and we did the water quality analysis as a group and I was involved in that. That was about a quarter of the time I spent online trying to find anything about the Aquaponics, the third quarter was driving around Buffalo and Western New York looking at different materials looking at going to hydroponic places going to stores that had equipment that I could use from pet stores to the Aquaponic stores to garden centers that kind of

> thing researching that way, and then the other 25% was spent ending in a barn putting the system together and testing it and actually time wise that was actually more than 25% because once I started the grow plugs it was every day. (…) So it is almost now, now it is almost more than just a research project, it's something that you have to tend to it is like a pet.

At the end of his summer research experience, Mr. Brown proposed that he would use his aquaponics systems to model for his students a sustainable system and to engage his students in the process through the creation of an Aquaponics Club and incorporation of the model into his curriculum. In his interview with the researcher, Mr. Brown stated that

> My goal was to research the how to do on an Aquaponic system and to build a small- scale model that I could bring into the classroom. With as evident by the gurgling noise in the tape is running and up and running in the classroom on a small scale, so I feel as if I had achieved that goal. I feel as though my goal was to come up with scalable model, I believe I'd do have scalable model and I have it in my classroom and I am very satisfied, and of course you take that the students, and then of course it is to have students getting involved and we are getting students involved, so that will be the ongoing.

Level of Use – What does the Summer Research Experience and Curriculum Goals look like in Practice?

Mr. Brown exhibits the characteristics of an individual who is at Level III: Mechanical Use of the LoU scale. Whilst he has his aquaponics system running in his classroom, the implementation of that system into his planning and instruction is limited. At this stage of use, Hall and Hord (2001) describe use of the innovation to be short-term, limited to day-to-day implementation. Furthermore, observations of his practice illustrate a "disjointed and superficial use" (p. 236) of the system.

Knowledge of Interdisciplinary Science Inquiry

Mr. Brown has a general understanding of interdisciplinary science inquiry and through his aquaponic system and other activities is making attempts to incorporate certain aspects of ISI into his classroom practices. When asked to explain what he interprets ISI to be, he explained that it involves incorporating other disciplines. He gave the example of needing to understand physics, biology, geometry, and economics when studying different topics in environmental science. Even Mr. Brown understood that through the process of ISI, other disciplines beyond the one being studied are necessary to successfully complete tasks and understand concepts within that one area, he lacked an understanding of the different components of ISI, particularly in regards to the specific engineering practices. When asked during the fall interview to explain how the focus of science and engineering practices in the new curriculum, in reference to NGSS, would change his teaching practices, he was unable to see how that would happen or how it would fit into his current curriculum, as he did not believe he currently uses elements of engineering in his teaching.

When asked to explain what types of strategies he would use to teach ISI, Mr. Brown explained that he would use those that he has used in the past to teach inquiry. He was not able to differentiate between the two different forms. Mr. Brown attributes his inability to implement strategies that move beyond inquiry to interdisciplinary science inquiry to the focus of his summer research experience. The summer research experience, for Mr. Brown, was about practicing science, not about developing curriculum, particularly a curriculum connected to ISI, that he could immediately implement into his classroom.

Acquiring Information and Sharing

Through his own personal research in the summer regarding the building of a classroom aquaponics system and the advice he has received from university STEM graduate students, Mr. Brown has shown that he is attempting to acquire more information about how to use the system in his classroom. He has attended two monthly professional development sessions: the first where he shared with the ISEP community his summer research experience and the second session that focused on defining and identifying elements of interdisciplinary science inquiry in teachers' summer research experience. Mr. Brown also attended a professional learning community (PLC) meeting that was run other researchers and graduate students in the ISEP grant that was focused on issues relating to implementing environmental science concepts into teachers' classroom practices.

Assessing

Student interest in the aquaponics system and the questions that stemmed from that interest is how Mr. Brown is assessing his use of the model in his classroom. Mr. Brown sees that through the questions that students ask or the remarks that they make regarding the vegetables growing or the fish developing in the tanks as an opportunity to start the process of inquiry with his students.

> An example of a current teaching practice that I have modified or changed as a result of my summer research experience, I think again just having it here where the kids can see it and almost every class I would say a majority of the students take a detour coming in or going by just looking ... You know, Mr. Brown why are these getting so big or what are these new ones or that kind of thing. So I think that the spark to inquiry in the classroom and I think it is a good thing…

Planning, Status Reporting, and Performing

Mr. Brown teaches four sections of environmental science and in that course, the first unit of study is sustainability. At the end of his summer research experience, Mr. Brown proposed that he planned to incorporate his aquaponics system into this particular unit of study by allowing students to visualize and make observations on how this system represented sustainability. Unfortunately, as this unit was at the beginning of the school year, Mr. Brown's system was not fully up and running at the time. However, he related that once his model was functioning properly, he was able to refer back to that first unit and explain how the system was an accurate representation of a sustainable system.

In Mr. Brown's freshman environmental science class, observations of the model are also being used to illustrate how nutrient cycling within a system takes place. During one observation of this class, students were introduced to the aquaponics system as a model of nutrient cycling. The class period began with students completing a KWL on nutrient cycling. Students were then given an opportunity to share what they remembered about nutrient cycling and through a series of questions Mr. Brown probed students to develop a better picture of what they knew and did not know. The students then watched a 12-minute video on how to make an aquaponics system. This was not an educational video and very technical as it detailed how to go about constructing and managing an aquaponics system. Students were asked to identify all the examples of nutrient cycling they saw in the video. After going over the worksheet, Mr. Brown directed his students back to his system and he talked to them about how the system cycled nutrients. The class period is only 40 minutes and by the time students made it back to the classroom model, they only had about 10 minutes to observe the model and complete a color-coded worksheet on how the nutrients were being cycle. As with the first unit when the model was not fully functioning, it was evident that Mr. Brown is still working through how to efficiently incorporate the model into his classroom practices. When the video was playing, it was observed that over half of the class was not engaged. After the first 3 to 4 minutes of the video, those disengaged students had their heads down on their desks, were looking around the room, or were conversing with the neighbors. Once students went back the model, there was little time for them to have Mr. Brown explain the different aspects of the model and how they worked together and given that so many students were in the class, several of the students towards the back were unengaged with this part of the lesson and were conversing with those standing near them.

In addition to teaching four sections of environmental science to ninth graders, Mr. Brown also teaches an advanced environmental science course to students in 10^{th} through 12^{th} grade. For these students, he plans to have them participate in a writing contest sponsored by the Sierra club. The focus of the papers that they will be writing is on sustainability and he hopes that they will use the classroom aquaponics system in their papers as a model of sustainability. In this advanced class, he is using his aquaponics system to test for nitrates. He is also using those results to compare with the results students obtained from testing water samples of a lake.

> In our environmental lab we are testing water samples from a lake and we are testing nitrates. And nitrates are one of the one of the variables in our aquaponic systems. So we are testing these water samples and walk right over and test the tank… And the kids go “We have a lot of nitrates in the tank!” And so they know that, and then we can expand that to so what does that mean? What do we have to do? Is it too much? Where is the balance?

Contextual Factors that Limit ISI Implementation

The nutrient cycle lesson that Mr. Brown conducted with his ninth grade environmental science students illustrates that while he is trying to incorporate his summer research and aspects of the ISI framework into his classroom practices, there are stumbling blocks present that limit the effectiveness in which he can do so. One of the major factors identified in the lesson, as well as by Mr. Brown himself, is time.

> You know time is certainly something, doing the model and setting up the model and all that. If we hadn't had the summer research I would never have done it because everything else going on with teaching and family ends outside and the extracurriculars. I wouldn't have had that block of hours set aside to work on that. I think you see that in teaching, you have teachers develop pet projects that they want to do and they are motivated intrinsically to do it. While we'd like to do that, we don't because we don't set aside the time either because of what because of the time difficulties.

In regards to his students' ability, Mr. Brown acknowledges that lack of background knowledge in science and other subjects as well as a basic understanding of the nature of science, places limitations on what he can do with his students. From their lack of experience with the environment outside of an urban setting to their limited skills in mathematics, Mr. Brown recognizes that in order for ISI to be successful with his students, the experiences must be scaffolded.

In summary, Mr. Brown illustrates a teacher who is starting to develop an understanding of how research can be incorporated into his classroom practices. The decision to build an aquaponics model during his summer research experience was directly connected to new and expanded learning experiences that he wished to provide for his students. Whether it was to provide them with a visual model of sustainability to help them improve on state exams or begin the process of inquiry by asking questions and making observations about the model, Mr. Brown had a clear vision of how his summer research experience could be connected to his curriculum and to his classroom practice. However, what was limiting Mr. Brown's ability to extend his implementation beyond mechanical use where the lack of time and planning he had to develop a curriculum that was more directly linked to the four dimensions of interdisciplinary science inquiry. The next case study, Mrs. Williams, illustrates a teacher who has moved beyond the mechanical use of ISI and through thoughtful and explicit curriculum development has created a learning environment for her students that is more closely linked to the different aspects of interdisciplinary science inquiry.

Case III – Mrs. Williams

To Mrs. Williams, science is everything. For this veteran teacher, who has been teaching in the district for 43 years, having students involved in science means that they, the students, are involved in inquiry, in authentic problems where they learn not only the scientific concepts, but also how to make valid explanations that are based on evidence. Mrs. Williams wants her students to "own the world." Through exploration, experimentation, and evaluation, Mrs. Williams hopes that her students will learn to think and act like scientists and see how science connects to their lives, now and in the future.

The design and implementation of Mrs. Williams' summer research experience was directly connected to the purpose of connecting science to the lives of her students and by providing them with more authentic experiences in science. Her summer project was comprised of three parts. The first involved collaboration with the other science staff at her school to create and push for a sixth grade science curriculum that had students involved in science everyday. The second component was through her involvement in a regional meeting of teachers that spent time discussing how they could make the science experiences for their students more place-based. Through her work at the Academy, Mrs. Williams, along with the other 7th grade science teacher at her school, recreated a SEPUP cholera unit to be based in the region surrounding North Park Elementary School. During a discussion that took place in the summer, Mrs. Williams explained that

> We're usually doing project-based things like, well SEPUP calls it mapping death with cholera. I just found out that cholera was the same problem in this area at the same time, so I just spent the last three weeks writing a whole curriculum, so that the kids can say "hey I know I know were Heron street is. What you mean that happened?" I've got the maps of that. I think they take ownership that they've got it.

The third component of Mrs. Williams' summer research experience was returning to a research lab to learn about how to use probes to test and monitor the waterways that runs near the school where she works. Working with the environmental teacher cohort, Mrs. Williams and other science teachers at her school were trained by university STEM graduate students to use Ross Probe ware to study the water quality of local waterways. Testing samples, both in the laboratory and in the field, the teachers learned how to use ion selective electrode probes to measure levels of nitrates, sodium, and chloride found in those water samples. Mrs. Williams and the team of science teachers at her school plan to develop as a result of their summer work a long-term study of the quality and health of the waterways at their school as well as create a partnership between their school and a neighboring high school. In the poster summarizing their experiences, the teachers summarized their plan for the future by writing …

> We plan to undertake a long-term study of the quality and health of these waterways and use it as a learning tool to encourage environmental stewardship of their (i.e. the students) community. In transforming our science program to an environmentally focused one we will align with North Park High School where many of our students continue their education. Aligning both schools to an environmental theme in the science programs as well as introducing state of the art sampling and testing techniques in grades 5 to 8 will lay the foundation for future scientists.

Level of Use – What does the Summer Research Experience and Curriculum Goals look like in Practice?

The focus of Mrs. Williams' summer experiences centered on how she could make her students' classroom experiences more meaningful and authentic in terms of practicing science as well as making her current curriculum better connected to their lives both in and outside of school. Through collaboration with other teachers at her school, Mrs. Williams exemplifies a teacher who has reached the Level V: Integration on Hall et al.'s (1975) LoU scale. This level of use is characterized by collegial planning between teachers involved in the ISEP project as they adapt their research experiences to best benefit their students needs (Hall & Hord, 2001).

Knowledge of Interdisciplinary Science Inquiry

Mrs. Williams' understanding of interdisciplinary science inquiry stems from her work with the SEPUP models. Through her past work with these models, Mrs. Williams illustrates that she has developed a strong knowledge base of what it means to incorporate inquiry into her classroom. Mrs. Williams further related using the models to interdisciplinary science inquiry. When asked to explain how the SEPUP models illustrate interdisciplinary science inquiry, Mrs. Williams explained that

> I think it follows exactly the SEPUP model. You don't teach biology one year and then teach Earth science next year, you put everything together. When they are doing an activity they are doing writing, their doing history, they're doing all of the sciences together. It's not this little piece and now let's go to this little piece. They see how it all comes together.

To illustrate what she meant by this, Mrs. Williams explained how the seventh grade students work with their technology teacher to build CO_2 cars and because the students also write up a newspaper article on their project and create a logo for their cars, they receive credit for the project in their English Language Arts and art classes.

> We've been doing it for a while. Let's say I want to want to teach speed and acceleration. Our technology teacher has them build CO_2 cars. I have them collect data and do the analysis. We do the math in my class in science and they do rates at the same time in math and then they write out. I make them write up a newspaper article and then they turn that into me and will get credit for it in English. The art department has them come up with a logo for their cars. It's bringing all those things together and trying to show the kids that we all doing the same thing.

Even though art and ELA extend connections beyond the fields of science and engineering, this example illustrates Mrs. Williams' ability to coordinate with others, both in and outside of her content area, to improve the learning experience for her students.

Mrs. Williams understands that as her students become accustomed to participating in projects, like the cholera project and the CO_2 car building project, they will develop their critical thinking skills and come to own their knowledge of science. In order for that process to be successful, students have to trust that their opinions and thoughts will be valued and that they have a voice in the learning process.

> You have to get the kids own what they're doing and trust you so that they will take those risks. Sometimes in here kids will say the strangest things, but if they know it's okay because no one will put them down, they'll just say you know what do you really think about. If you don't have that trust, everything falls down.

The one area within the ISI framework that Mrs. Williams acknowledges having limited knowledge about is in the implementation of engineering and technology. She accounts for this limited knowledge by stating that this is an area that they have not had to teach in the past. With the skills that she and her colleagues currently possess, she is also unsure of how it could be successfully integrated into the classroom.

> Our whole department needs a lot of, um, more training in engineering. I mean it's not just something that has ever been touched on, which is why I'm going to this thing to see if I can bring things back. That is our weakest area. We can deal with the other ones but we tend to shy away from it (i.e. engineering) because we're weak in it.

Acquiring Information

Mrs. Williams made use of multiple resources to adapt the original SEPUP Dr. Snow Cholera activity so that it also had a connection to the local school community. When explaining how she collected data on individuals who died as a result of the cholera outbreak in the community surrounding North Park Elementary School, Mrs. Williams described hiking through the local cemetery looking for death dates that matched the time period of the outbreak. Upon exhausting that resource, Mrs. Williams reached out to the local historical society and was able to collect information about not only those who died during the outbreak but also of the geography of the region during that time period.

Also, given her acknowledged weakness in implementing aspects of engineering into her curriculum, Mrs. Williams volunteered to join local teachers for a day of professional development at a local engineering company. The program that this company started as a community outreach was designed to help middle school teachers incorporate more engineering in their classrooms.

Sharing

On multiple occasions, Mrs. Williams discussed and shared with others about the changes that she and her science teacher colleagues were making as a result of their work with the ISEP project. During one of first the professional development sessions, Mrs. Williams shared with teachers from other schools how she and the science team changed the curriculum at their school. These changes included adding one hour of science every day for the sixth graders, instead of just 20 minutes every other day, as well as the modifications they had made in current 7^{th} and 8^{th} grade curriculum to incorporate more place-based science and their plans for incorporating Probe ware in their classrooms.

Mrs. Williams and her fellow science teachers also hosted a STEM parent night at their school. Families with students in grades 6 through 8 were invited to join the science faculty and administrators for a night of science. In addition to explaining to parents the changes that had been made with the science curriculum, families worked together on two science activities. Over 20 different families from the community attended the parent night.

Assessing, Planning, Status Reporting, and Performing

Prior to beginning the summer research experience, Mrs. Williams and her fellow science teachers at Southside Elementary set out to make create a science program that focused on authentic science investigations and would enable students to become more environmentally conscious of their neighborhood, particularly with regards to the health of the local waterway systems. Mrs. Williams and her colleagues restructured their curriculum to provide their students with more opportunities to experience real world problems that were based locally in their community as well as experience science more frequently. During one of the discussions held between Mrs. Williams and the researcher, Mrs. Williams expressed her opinion on how her summer experiences and changes that she and her colleagues have made in their curriculum will impact their students.

> Int: So, where do you think this will go with your experiences with this project?
> Mrs. Williams: I think that by the end of this grant we will be phenomenal. Already what we have done is decide that we are going to be an environmental middle school. We have set up the curriculum so it scaffolds up. As I said, we did the cholera unit and then in January we are hoping, see we still don't have any probes, so in January we are hoping that we can begin teaching the kids how to use probes and then the second half of the year get, just begin to get their feet wet, so that our seventh graders and eighth-graders are really proficient in using the probes. Our fifth and sixth grade will just get them to "this is a probe." We put a new curriculum in over the summer for sixth-grade that is working very well and they are in a long-term project, so it is up and running.

Assisting Mrs. Williams and the other science faculty at the school are several university STEM graduate students. In collaboration with these graduate students, Mrs. Williams has been able to incorporate more technology into her practices. Through the use of Google Earth to map cholera victims and other applications, like Excel, Mrs. Williams' students are learning to use the tools of today's scientists. Also, two of the STEM students have assisted Mrs. Williams and the seventh grade science teacher in creating an environmental club that partner with the environmental club at the nearby high school.

Contextual Factors that Limit ISI Implementation

The contextual factors that Mrs. Williams identified as limiting her ability to implement interdisciplinary science inquiry to the level she desires are similar to those identified by previous teachers. The concern that Mrs. Williams expressed as limiting her ability to do science and inquiry-based science was the limited exposure students have when entering 7th grade. Prior to students entering 7th grade, Mrs. Williams described their experiences in science to be sporadic and disjointed.

> Everything is totally disjointed and they would get little smatterings of ideas, but never put anything together. They never did any labs. It drove me crazy. They couldn't use basic lab equipment. They didn't understand one of variable was and why we would have a variable or where they would be important. Until they get to seventh grade, they've never even heard of that term. We have to spend half of the seventh grade year teaching them skills before we can even start to teach them science.

The gaps that students in their knowledge of science and basic science skills places limitations on how much "new" material can be taught and extensions beyond the basic science skills and knowledge can be made. It is not, however, students lack of science that limits their ability to do science; it is also their limited knowledge and ability to do write and complete basic mathematics and their ability to see how concepts in these areas carry over to science.

> Mrs. Williams: Math is a big one. They are afraid of things. The problem is that what they will do with me in science, they will not take back to math. Like they are doing rates in both classes, but they see no connection. What they don't see is that one million in science, is one million in math. They don't have that. They don't understand one half or one part in two is the same thing. I don't know how we are going to get that knowledge, but we are trying. It's like with their writing. "We don't have to spell it right in English, why do we have to spell is right in science?" We need to be more on the same page.

Mrs. Williams partially accounts lack a common planning time for the weaknesses student have in seeing connections between disciplines. A time where teachers in those different disciplines can sit down together and discuss how to integrate their curriculums.

> Our main problem is that we don't have common planning time. We have to catch each other on the way out the door. We used to have, but they took it away from us. We used to be able to sit down and say here we are doing density, you are doing population density, do the math of density, and in English do some poems on density, and the technology will come up with something.

Other than student difficulties, the other factors that limit Mrs. Williams' ability to fully implement her summer research are equipment and time. As was mentioned previously, while Mrs. Williams hoped to have her students collecting data right away, they did not have any probes at the beginning of year and hoped to have them by the start of the second semester. Mrs. Williams also recognizes that in order for students to run experiments and conduct inquiry projects, the class periods need to be longer. With the current 40-minute time block students get started and get into the project or experiment, but then not before too long have to stop and wait to continue until the next day.

As stated previously, Mrs. Williams illustrates a teacher who has moved beyond the mechanical use of ISI and through thoughtful and explicit curriculum development has created a learning environment for her students that is more closely linked to the different aspects of interdisciplinary science inquiry. Through collaborations with colleagues, STEM researchers, STEM graduate students, and community members, Mrs. Williams was able to redesign aspects of her curriculum that established connections with the lives and needs of her students. Her understanding that students' need to be offered the opportunity to experience science in ways beyond the textbook, through projects where they must search and solve problems on their own and with collaboration with their classmates, and by having to defend their conclusions with evidence, strongly indicates that Mrs. Williams on the path to becoming an exemplary example of what ISI can look like in today's science classrooms.

Conclusion and Discussion

Theme #1: To Promote "Buy-In" and Implementation of ISI, Teachers' Research Experiences Must be Aligned with Their Perceived Curricular Goals.

The main conclusion that can be made about how teachers view their summer research experience influencing their classroom practice is that when the research experience matches the proposed goals and interests of the participating teachers, there is more buy-in to developing and using their experiences within the classroom. The beliefs held by the participating teachers regarding their summer experience, as Roehrig and Kruse (2005) indentified, were directly connected to how they set out to plan and implement aspects of those experiences in their classrooms. Their beliefs became the filter through which to gauge their summer research experiences (Coenders et al., 2008). When their personal beliefs and knowledge regarding their curriculum matched the research experience, they viewed it as being more beneficial and were therefore more likely to implement it. However, when they interpreted the experience as not matching their school curriculum, their view of that experience was along the lines of it being an interesting opportunity, but was something that they could not do in their classrooms or that their students would be successful with.

As was the case with Ms. Lewis, she perceived that her summer research experience did not align well with the concepts that she focused on in her curriculum. Her inexperience in chemistry and the lack of chemistry within her curriculum lead Ms. Lewis to view her experience as enjoyable, but not translatable to her high school forensic science class. The experiences of the other two teachers highlighted in this study better aligned or were made to align with their curriculum. For Mrs. Williams and Mr. Brown, they used their summer research experiences to revamp aspects of their curriculum so that the student learning experiences were more meaningful and connected to the lives of their students. Instead of passively stepping into a research experience, they both were active in designing that experience so that it best met their interests and perceived student needs and interests.

Theme #2: Teachers' Understandings of ISI Impacted the Perceived Relevance of Their Summer Research Experience

The participating teachers' views regarding the relevance of their summer experiences were affected by their understanding of what ISI was. Knowledge and beliefs about science curriculum is one of the five components of PCK as defined by Magnusson et al. (1999). Interdisciplinary science inquiry represents a theoretical framework with which to design science learning around and as such represents an aspect of science curriculum that teachers within this project were asked to develop and implement into their classroom practices. This form of science curriculum knowledge is aligned with Magnusson et al.'s (1999) second dimension: knowledge of specific curriculum programs and goals.

As exemplified with Ms. Lewis, her limited knowledge of ISI in turn limited her ability to see how her summer research experience was relevant to her curriculum and classroom. Her perception of ISI was centered on how she could incorporate math and ELA into her curriculum. In regards to the four dimensions of the ISI innovation, there is no mention of designing her curriculum in such a way that introduces students to authentic problems that are grounded in the discipline or other disciplines within the fields of science and engineering. Furthermore, Ms. Lewis acknowledged that did not involve her students in inquiry, stating that most of the students' knowledge was developed through worksheets and prescribed laboratory activities. Thus, an inquiry experience that incorporated multiple disciplines of science and technology was perceived by Ms. Lewis to be of limited value in her classroom.

As mentioned previously, "new curriculum ideas will not affect classroom processes until teachers have had sufficient opportunity and support to internalize the teaching repertoire, particularly beliefs associated with those actions" (van den Akker, 2003, p. 443). Therefore, in order for teachers to make permanent changes in classroom practices, one must take into account the beliefs of teachers as the implementation of new curriculums and ideas often requires teachers to transform or adapt their understandings of teaching and learning (Powell & Anderson, 2002).

Theme #3: Levels of Use is Directly Connected to How Teachers View their Summer Experience Matching their Curricular Goals

As there is currently no direct measure of interdisciplinary science inquiry curriculum knowledge and practice of that knowledge, the Level of Use scale was used to identify how teachers were implementing their summer research and ISI framework in practice. The teachers in this study demonstrated a varied spectrum of use of both their research experience and the ISI framework. This spectrum mirrors Pop et al.'s (2010) findings regarding the percentages of teachers who implemented aspects of the RET program in their teaching. Even though the participating teachers professed to have gained more knowledge of science and skills related to science research, it did not necessarily result in changes in their curriculum or enactment of that curriculum. From nonuser to user, the teachers in this study took specific actions to implement or not implement aspects of interdisciplinary science inquiry.

In many ways, the enactment of their curriculum goals was directly connected to how they viewed their summer research experience fitting with their curriculum. For those like Ms. Lewis who believed that her experience did not fit with the current curriculum or with her students made the decision to not implement any aspects of it into her classroom. Furthermore, the perceived disconnect between the experience and the classroom lead them, as Ms. Lewis exemplifies, to take no further actions to learn more about interdisciplinary science inquiry and how it could be implemented in classroom practices. As Mr. Brown makes continued use of the aquaponics system in his classroom, he will hopefully transition from mechanical user to routine user as he reflects upon what works and what does not. His long-term goals for the project indicate that he sees a future in using the model in the classroom and perceives that through its use student interest and learning in science, particularly environmental science, will increase. Mrs. Williams' level of integration indicates the buy-in and confidence that she has in implementing and conducting inquiry in her classroom. The prior experiences and training that she has done to develop and use inquiry with her students illustrate the potential that others within the project have with continued practice and support.

By using LoU as the framework to classify teachers' enactment of their summer research and curriculum goals, the research team can "understand where each person is and to determine appropriate support for further change process" (Hall & Hord, p. 91). As the project moves into its third year and second year of summer research for teachers, the research team needs to assess what forms of interventions are necessary for teachers at each level of the LoU scale.

Theme #4: Cultural and Ecological Factors Get in the Way of Doing ISI in the Classroom

As defined previously, contextual factors are comprised of two different types of factors: cultural and ecological (Hall & Hord, 2001). Both types were identified by teachers within the study as impacting their abilities to implement their summer research experiences and interdisciplinary science inquiry into their classroom practices.

The cultural factors identified by teachers included their perceptions about the ability of their students to be involved in interdisciplinary science inquiry and their own abilities to lead activities of that nature. Ms. Lewis indicated that she had a limited understanding of what ISI meant and how to implement aspects of ISI in her classroom. This also extended to how she saw her summer research experience as being connected to interdisciplinary science inquiry and to her students.

All of the teachers highlighted in this study identified students' academic weaknesses as being a major limiting factor to even conducting basic inquiry investigations in the classroom. The students' weaknesses reached beyond science and encompassed their reading and writing abilities as well as their ability to do basic mathematics. As Gilbert and Yerrick (2001) found in their study on teachers' perceptions of low-track students in North Carolina, the perceived deficit in student knowledge guided the teachers' curricular decisions in planning for and implementing their summer research experiences into their classrooms. This particular factor did not affect the three teachers in this study equally though. For Ms. Lewis, her students' academic struggles lead her to not include any aspects of her summer research in her classroom. The emphasis on teaching students content first lead Mr. Brown to use the aquaponics system as an observational tool rather than a tool of inquiry. For Mrs. Williams, while she recognized that her students had weaknesses in math and grammar, she saw inquiry as a way to allow all of her students to succeed. The only difference between her students was where they started out.

> Mrs. Williams: Everybody starts at whatever level they are and then they work with their group up to wherever I want them to be, but at no point… I mean you could come in here and never had science at all and you will be successful, it might take you a little bit longer, but you will be successful. And you will own it.

The main ecological factors that the teachers indentified were similar to those found by the Jones and Eick (2007) study: time and resources. The amount of time that it takes the teachers to plan and set up inquiry experiences, to the time it takes away from teaching other curricular requirements during the school year, to the time is takes for students to successfully complete those inquiry experiences were major stumbling blocks for the teachers. The current 40-minute class period limited how much students could complete in one day. This lead to rushed lessons, as was the case with Mr. Brown, and frustration on the part of students to not finish a task or on the part of the teacher to have such fragmented instruction, as was the case with Mrs. Williams. The lack of equipment or improperly functioning equipment at the beginning of the school year had many of the teachers putting off their plans to implement their summer research goals. Another factor identified with regards to the equipment was the inability to use the type of equipment that the teachers had used during their summer research experience in their classrooms or with their students. This inability was identified to be due to the cost and type of equipment that they used over the summer and the need for the equipment to user-friendly for their respective student population.

Implications

Interdisciplinary science inquiry represents a shift in how science should be taught in K-12 schools. With an emphasis on inquiry that blurs the lines between disciplines, incorporates engineering and technology, and asks students to use the knowledge and skills they develop to solve real-world problems, science teachers may need to change the way they approach science and science teaching. As with the three teachers highlighted in this study, the buy-in and implementation of ISI will vary amongst science teachers, which in turn will impact the success of not only the ISEP project, but also with the Next Generation Science Standards.

Several factors for implementing interdisciplinary science inquiry were identified in this study. One of those factors relates to the role the participating science teachers play in designing their summer research experience. This study found that when the research experience of the teachers match their interests and goals for their classrooms the likelihood of them trying to implement ideas and concepts they learned through their research experience increases. Also, during the summer research experience, the teachers need to be more than passive observers. As it is with students in the classroom, when the teachers are more actively engaged in the process of research and design, the more likely they are to see value in the experience and in how it can be used to enhance their students' learning experiences. These experiences though need to be directly connected to the curriculum that the teachers are expected to teach. This direct connection could be facilitated in a number of ways and include: (1) a focus on curriculum development in the summer alongside of the science research experience; (2) regular discussions amongst researchers, STEM students, and science teachers about what ISI is to them and how the research illustrates aspects of ISI and how those aspects could be implemented into the classroom; (3) with the aid of STEM faculty, STEM students, and members of the science education research team the creation of activities that all students can be engaged in; and (4) further professional development opportunities for teachers to work collaboratively with each other and others within the ISEP project. As the findings in the Pop et al.'s (2010) and Yerrick et al.'s (1997) studies imply, it is not enough for teachers to gain experience in laboratory and research settings, connections must be made and experiences must be offered to assist teachers in taking those research experiences back to their classrooms.

The main limitation to this study was the limited sample of available participants with which to select and learn from. Several factors led to participants being selected out for this study. These factors included no summer log sheets highlighting the teachers' interpretation of their summer research experience, unwillingness to be observed in their classrooms, unwillingness to participate in the interview process, and absences from research sessions and/or professional development workshops. While this limited sample of teachers limits the extension of the study, it did provide insight into improvements that need to be made as the project moves forward into its second year of summer research. Those improvements include providing teachers with greater assistance in writing their summer research proposals through a proposal writing workshop and changes made in the design and implementation of the projects professional development workshops offered.

At the forefront of this is how teachers go about the adoption process and in what ways the ISI framework aligns with their perceptions on how and what to teach and how their students learn best. "Teachers' understanding of curriculum materials, their beliefs about what is important, and their beliefs about the roles of the students and the teachers all strongly shape their practice" (Coenders et al., 2008, p. 332). As standard-based reform within the United States continues on its path of developing standards for improved scientific and interdisciplinary scientific inquiry in science classrooms across the nation, the value of understanding how teachers perceive and enact these new standards for learning will be a main predicator in the success of these new reforms on impacting student science achievement.

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Table 1
Levels of Use (LoU) chart (Hall et al., 1975)

Level of Use	Title of Level	General Description
0	Non-Use	Characterized by little to no knowledge of innovation, no involvement or use of the innovation, no plan to become involved or use it in the future
1	Orientation	Characterized by the acquisition of knowledge and exploration of the value and demands of implementing the innovation, no use of or plan to use innovation
2	Preparation	Characterized by the preparation to use the innovation for the first time
3	Mechanical Use	Characterized by short-term use that is similar to Mevarech's (1995) stage of survival involving a cookbook or technical use of the innovation.
4A	Routine	Characterized by a more routine use of innovation that is similar to Mevarech's (1995) stage of exploration and negotiation. The approach to innovation is more positive, but focus is still on how it affects them rather than on student learning.
4B	Refinement	Characterized by the ability to vary the use of the innovation to increase the impact on student learning. Variation is based on both short-term and long-term goals for students.
5	Integration	Characterized by the ability to collaborate with colleagues who also use the innovation to increase the impact of the innovation on student learning.
6	Renewal	Characterized by the ability to reevaluate the quality of the innovation use and make modifications to increase its impact on student learning.

Table 2 Demographics of Schools Highlighted in the Study

	West High School	Central High School	North Park Elementary School
Student Population	600+	~1000	~1000
Percentage of Students Receiving Free Lunch	77%	69%	70%
2010-2011 Reported Student Demographics	0% American Indian or Alaska Native	0% American Indian or Alaska Native	1% American Indian or Alaska Native
	90% Black or African American	86% Black or African American	21% Black or African American
	5% Hispanic or Latino	5% Hispanic or Latino	10% Hispanic or Latino
	1% Asian or Native Hawaiian/Other Pacific Islands	2% Asian or Native Hawaiian/Other Pacific Islands	2% Asian or Native Hawaiian/Other Pacific Islands
	3% White	5% White	64% White
	0% Multiracial	1% Multiracial	3% Multiracial
Attendance Rate	76%	76%	90%
Graduation Rate	54%	49%	N/A
Dropout Rate	17%	20%	2%
Regents-level Science Courses Offered	Regents Living Environment Regents Earth Science	Regents Living Environment Regents Earth Science Regents Chemistry	Regents Living Environment

Sources: 2012 New York State Report Card.