Understanding In-service Teachers' Orientation towards Interdisciplinary Science Inquiry.

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Abstract

The notion of a *science teaching orientation* is central to understanding a teacher's Pedagogical Content Knowledge (PCK) and the relationship between their knowledge, beliefs and practice (Abell, 2007). Teachers' science teaching orientations act as filters or amplifiers in shaping teachers' overall classroom behavior. However, very few empirical studies have identified science teachers' orientations in relation with different components of PCK and none toward interdisciplinary science inquiry. Through the use of interviews, and multiple classroom observations we attempt to understand teachers' conceptions toward each component of PCK and their overall oreintation(s). We present three case studies depicting teachers' orientations on a continuum. We present our teachers' orientations in the form of profiles. These profiles provide us insights about teachers' conceptions toward science teaching and learning and their classroom behavior. This also helped us understand teachers' struggle with understanding and implanting interdisciplinary science inquiry in the classroom. Implications for professional development and the use of profiles as an exploratory research tool are discussed.

Introduction

Educators and scientists supported Science inquiry as an approach for science teaching and learning almost three decades between 1960–1990. This support and interest was reflected in such the reform documents as Benchmarks for Science Literacy (AAAS 1993), the National Science Education Standards (NRC 1996), and Inquiry and the National Science Education Standards (NRC 2000). These publications influenced state standards and the place of inquiry in school science programs. These documents shifted science teaching and learning from *methods* to *process of science* and *scientific inquiry*. Research has progressed in last fifteen years and has advanced our understanding about science teaching and learning leading us to yet another science education reform in the form of the Next Generation Science Standards (NGSS) based on a framework for K-12 science education framework (NRC, 2011). NGSS uses a term science practices instead of inquiry process skills referring to practices being an evolutionary step to inquiry process skills and expectation of students becoming proficient in what they do and learn. NGSS has proposed *crosscutting concepts* that blur traditional boundaries between disciplines highlighting interdisciplinary nature of scientific inquiry. In the K-12 context, NGSS uses the terms “engineering” and “technology” in the broad sense by engaging students to learn unified concepts and systematic practices to design to achieve solutions to human problems.

The trends in the most recent reform document toward emphasizing crosscutting concepts and science and engineering practices present a new vision for scientific inquiry, which may be called interdisciplinary science inquiry (ISI). This focus on ISI demands understanding of teachers’ conceptions about ISI and efforts to implement it in the classroom. Studies conducted in an earlier era of US science education reform suggested that to better support the transition of teacher practice to a more constructivist and inquiry-based approach, teachers’ beliefs about teaching and learning of science must first be considered (Brickhouse, 1990; Cronin-Jones, 1991; Duffee & Aikenhead, 1992; Tobin & McRobbie, 1996; Bryan and Abell, 1999; Levitt, 2002). Understanding teachers beliefs towards teaching science and then comparing these to the goals of reform will afford professional developers the knowledge needed to then select the best practice for professional development (Yager, 2005); and in particular, one that meets the professional needs of teachers (Loucks-Horsley et al., 2003; Park Rogers et al., 2007).

In this study, we examine secondary, in-service teachers’ conceptions and orientations towards interdisciplinary science inquiry. Before we go into details of our paper however, it is important that we first clarify our interpretation of the teachers’ conceptions. Hewson and Hewson (1987) used this term, which includes components related to teaching, content, learners and their knowledge, learning, and instruction. They further described “teacher thought” as teachers’ theories and beliefs, their planning, their interactive thoughts and decisions; and “teacher action” as observable effect on teachers’ and students’ classroom behaviors and achievements. They also note that teachers’ conceptions of teaching, which influence the decisions they make about teaching strategies and content, and the reasons they give for choosing the content, will be reflected in their instruction. In this study we have defined orientations as teachers’ conceptions and behavior about science teaching and learning (Nargund-Joshi, 2012).

Following two research questions have guided our study:

(1) What are in-service teachers' conceptions towards each component of PCK while implementing ISI in practice?
(2) What are in-service teachers' overall orientations towards ISI? How do summer research experience and professional development programs play role in developing in-service teachers' orientations towards ISI teaching?

By answering these research questions, we hope to understand the complex relationship between teachers' conceptions towards ISI and their classroom practices. Analyzing teachers' orientations towards each component of PCK provides insights about teachers' strengths and struggles while implanting new curricular expectations.

Our current understanding of interdisciplinary science inquiry is based on our previous work (Nargund-Joshi & Liu, 2013). We derive four dimensions of ISI as: (a) Science and Engineering practices, (b) Crosscutting concepts, and (c) Disciplinary core ideas, (d) Drivers of Interdisciplinary Science Inquiry. We draw first three dimensions of our ISI framework from NGSS and the fourth dimension is drawn from the report on facilitating interdisciplinary science research (Committee on Facilitating Interdisciplinary Research, Committee on Science, Public Policy, 2005). The report defines drivers as, "kinds of motivation a scientist might respond to in undertaking interdisciplinary research" (p. 30). We believe this fourth dimension provides a broader context for situating first three dimensions of interdisciplinary science inquiry in a science classroom.

An examination of various educational journals reveals minimal research on teachers' conceptions of interdisciplinary science inquiry. Previous studies have indicated the importance of taking into consideration teachers' conceptions before expecting new curricular expectations to be implemented in the classroom by teachers (Bryan, 1999, Levitt, 2001). Our study will fill this gap by answering the research questions that focus on understanding teachers' conceptions towards different components of PCK while implementing interdisciplinary science inquiry in the classroom. This study also will shed light on how teachers' interpret and implement ISI and this could act as first stepping-stone in guiding teachers to implement expectations of NGSS. These new knowledge and understandings will help plan and implement future teacher professional development related to the NGSS in general and interdisciplinary science inquiry in specific.

Theoretical Framework

Teaching is a complex process that involves drawing knowledge from different knowledge bases. Pedagogical Content Knowledge (PCK) (Shulman, 1986) is often referred to as a "specialized knowledge" teachers have, thus differentiating them from content experts. Shulman (1986) defined PCK as "subject matter knowledge for teaching" and as "the ways of representing and formulating a subject that make it comprehensible to others" (p.9). The model consists of different hypothetical components: knowledge of science curricula, knowledge of instructional strategies, knowledge of assessment, knowledge of students' understanding of science and orientations towards teaching science. We use the theoretical framework of PCK in this study to understand how teachers perceive and employ interdisciplinary science inquiry in the classroom. Loughran, Berry and Munhall (2006) mention, " Recognizing one's own PCK is perhaps most evident when teaching outside an established area of subject expertise. No matter how capable a teacher might be when teaching his or her area of specialist subject, both skills and ability are immediately challenged (and typically found wanting) when teaching content with which there is familiarity" (p. 9). Many research studies in the US and across globe indicate that teacher' beliefs about science and teaching and learning must be first considered in order to implement science educational reform in the classroom successfully (Bryan and Abell, 1999; Cronin-Jones, 1991; Levitt, 2002). Therefore, in current study we examine teachers' knowledge, beliefs and practice about ISI. The relationship between knowledge, beliefs, and practice, is often referred to as being a messy construct (Pajares, 1992). Thus we use a construct of teaching orientations, which encompasses teachers' beliefs, knowledge and practice and serves as the conceptual framework for our study (Friedrichsen, van Driel, Abell, 2011). Science teaching orientation is a central component of Pedagogical Content Knowledge (PCK). Orientations shape and get shaped by different components of PCK. In this paper we examine in-service teachers' overall orientations towards ISI.

<Insert Figure 1 About Here>

Review of Literature

Identifying Science Teaching Orientations in Practice

In their description of PCK for teaching science, Magnusson et al. (1999) list nine orientations towards teaching science. They are: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5) activity-driven, (6) discovery, (7) project-based science, (8) inquiry and (9) guided inquiry. These orientations come from a variety of sources (see Anderson and Smith, 1987; Lantz and Kass, 1987; Marx, Blumenfeld, Krajcik, Blunk, Crawford and Meyer, 1994; Roth, Anderson and Smith, 1987; Tamir, 1983) studying teachers' practices in various contexts and most often at the secondary grade level.

In recent years however, only a few studies have focused on identifying nature of teachers' orientations towards science for the purpose of identifying professional development strategies. One example is Friedrichsen and Dana's (2005) study where they developed a card-sorting tool, which they adapted from Hewson and Hewson 's (1989), for the purpose of identifying teachers orientations based on the nine orientations Magnusson et al.'s (1999) describe. Using an interpretive case study, they analyzed the developed scenarios (or cards) which represented different approaches to teaching science; approaches representative of each of the nine orientations. They used these cards as part of an interview protocol and along with field notes from classroom observations searched to understand explicit connections between the teachers' observable classroom actions (i.e., their practice) and their beliefs and knowledge of the overall purposes and goals for teaching biology (i.e., their conceptions). With this combined approach, the authors were able to develop a representation of each teacher's science teaching orientation and learned that there were often multiple orientations occurring at once – those central to their practice and those that sat at the periphery, and becoming more dominant at certain times of instruction. In general, they learned that three types of goals shaped the teachers' orientations: 1) affective 2) the general expectations of the school (i.e., contextual), and 3) the subject matter. They further discuss probable sources like the influence of prior non-teaching work experience, the influence of professional development and collaboration, the influence of student feedback, time constraints, and beliefs about learning as factors influencing the development and enactment of teachers' orientations. The findings from this study help teacher educators and researchers to better understand the dynamic nature and sources of science teachers' orientations, factors influencing the enactment of orientations in practice.

Volkman, Abell, Zgagacz, (2005) on the other hand examined the notion of orientations at the college science level. The purpose of their study was to understand how a professor, teaching assistant (TA), and college students experienced inquiry-based science instruction in an undergraduate physics course designed for elementary education majors. While implementing this instruction, the professor and TA acknowledged that they both faced challenges and problems with trying to implement their teaching of science in ways that fit best with their orientation towards teaching science. The design of their course had three goals: 1) to provide the students with opportunities to do inquiry on physics concepts, 2) to have them make sense of the physics subject matter in contextualized and decontextualized situations (i.e., application to real world problems was significant), and 3) to understand inquiry as the basis for scientific work. The researchers, two of which were also the instructors of the study, discussed in their findings the problems they faced while co-teaching the course having come from different backgrounds. Volkman (the professor) struggled with when and how to give the right scientific information, Zgagacz (the TA) believed that giving the right answers to the students was her responsibility and that the students expected the teachers to give the right answers. Both of them also displayed discovery orientations. Activities chosen by the professor provided minimal assistance to the students while working and the students were expected to go through the meaning making process. The teaching assistant believed that scientists discover scientific knowledge and students could associate themselves doing discovery. The authors suggest that to help teachers, educators should help develop more of a guided inquiry orientation, where the teachers' role shifts from one of designing the experience to helping students develop and thus facilitate the co-designed experience.

In the limited research on orientations, they are often identified as emerging from the reform-based efforts but are not well supported by empirical studies. Also, few studies, except for Lantz and Kass (1987) and Hewson and Hewson (1989), take into consideration teachers' thought process while eliciting either their "perceptions of teaching" or "conceptions of teaching science". These two exceptions took teachers' thought process into consideration through the use of both observations and interviews. This approach prevented the researchers also from categorizing teachers into having only one orientation because as they noted, there were slight nuances between the teachers orientations as identified through the interviews and those they observed in the teachers' practice; thus indicating the need for multiple data sources when identifying teachers *full* spectrum of orientations and the relationship between their thoughts/views/conceptions and their actions or behaviors. It is for this reason that in our study we are exploring around 12 urban, in-service teachers' orientations representing secondary grades. Also, by gathering information through interview and classroom observations we hope to better understand the possible spectrum of their orientations previous researchers have noted (Friedrichsen & Dana, 2005; Friedrichsen et al., 2009; 2011; Hewson & Hewson, 1989).

Translating Orientations to Practice

It is often stated in the research that the relationship between orientations and practice is complex, and for various reasons teachers do not always translate their orientation for teaching science exactly into their science teaching practice (Friedrichsen & Dana; 2003, Volkman & Zgagacz, 2004). This complexity makes sense however when considering thatScience teacher practices are influenced by a number of factors, including the social and policy context in which they teach (Little, 2003), subject matter knowledge (Abell, 2007; Gess-Newsome, 1999), their beliefs about teaching (Jones & Carter, 2007; Pajares, 1992), and their pedagogical content knowledge (Abell, 2007; Davis, Petish, & Smithy, 2006) **(**as cited in Friedrichsen et al., 2011, p. 359).

Many empirical studies have indicated the significance of understanding teachers' beliefs (see reviews by Calderhead, 1996; Nespor, 1987; Pajares, 1992, Jones & Carter, 2007), but few have examined the connections between their beliefs about teaching, knowledge of teaching, and how these translate into teachers' practice (i.e. orientations); and even fewer yet have explored the potential influence of contextual factors on these connections (Abell, 2007). Of the few we found, Zipf and Harrison (2003) examined the dynamic relationship between orientations and practice held by two Australian elementary teachers. One of the teachers was identified as having a more traditional science teaching orientation, emphasizing the use of worksheets to teach the content. This teacher believed using a textbook helped the students to better engage with the content that needed to be learned and ensured a more accurate understanding of the content. Another teacher used a textbook; however, she relied on it more to help explain concepts the students were studying in class through explorations and other practices. The differences in these two teachers' use of texts in teaching science also influenced their orientation toward assessment. The first teacher favored mainly written exams at the end of her instruction, whereas the second teacher used more open ended formative assessments embedded throughout her instruction. Additional contextually-based factors noted in studies examining discrepancies between beliefs and practice include: student expectations (Volkman, Abell, and Zgagacz, 2005); school resources and or requirements (Beck, Czerniak, & Lumpe, 2000; Zhang et al., 2003); "testing" culture (Zhang et al., 2003).

Research Design

We employed a descriptive case study approach for this study. Yin (2002) defines a case study 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). This study attempts to understand how in-service teachers' develop an understanding of interdisciplinary science inquiry after participating in an authentic inquiry experience of summer research and other professional development opportunities throughout the year with university faculty members and graduate students.

A total 58 in-service teachers participated in research projects in the summer. These in-service teachers worked with different scientists in various science disciplines. We are reporting a subset of teachers with different summer research experiences. We chose our participants working in each discipline to understand if their orientations vary according to type of discipline and mentorship experiences.

We collected data from multiple resources. All the teachers also maintained daily log sheets during their summer research expressing their views and experiences about interdisciplinary inquiry. Throughout the year, we had multiple observations for each of these teachers implementing ISI in their classrooms. We collected lesson plans and other planning resources that teachers utilized. We also interviewed teachers to understand their conceptions about interdisciplinary inquiry after experiencing authentic ISI during summer. These teachers also participated in a three-hour session every month as part of their professional development. The sessions were designed based on the Pedagogical Content Knowledge (PCK) framework targeting each component of PCK in relation with ISI.

We employed an inductive approach to analyzing data. Two rounds of data analysis were completed on all data sources for each in-service teacher. We started our analysis with first examining each data source with respect to understanding each in-service teacher's conceptions about interdisciplinary inquiry. We also analyzed classroom observation notes and videotapes of each teacher's classroom sessions. After generating initial codes, we then grouped codes and formed themes across the various data sources with respect to answering each research question.

Interdisciplinary Science and Engineering Partnership (ISEP): Framework and Project

The Interdisciplinary Science and Engineering Partnership (ISEP) focuses on middle school and high school teachers and students to develop their understanding of interdisciplinary science inquiry. The project utilizes an innovative approach to teacher professional development among 12 high-needs urban schools via courses and interdisciplinary research experiences, development of science and technology classroom materials that are aligned with state science learning standards, and inquiry-based curricula. The ISEP also combines novel mentoring approaches and expanded professional learning communities to build leadership and resources for improving science education in high-needs/high-potential urban schools. The learning communities cultivate mentoring relationships involving middle and high school teachers and students, University at Buffalo and Buffalo State College STEM faculty, education faculty, undergraduate students and graduate students, volunteer STEM professionals, and/or parents.

Participants

In this research paper we report sub-set of 12 secondary in-service teachers participated in the National Science Foundation supported project from three different public schools from urban region of Western New York. These teachers participated in the various aspect of program such as summer research experience, monthly professional development programs that supported and developed teachers' understanding of ISI. The participants teaching experience ranged between eight to ten years.

<Insert Table 1 About Here>

Data Collection

We collected data from various sources, but interviews with teachers and classroom observations served as our main data source to elicit teachers' conceptions towards each component of PCK and overall orientations to implement ISI in the classroom. Interviews were conducted at times and locations mutually agreed upon by one of the authors and study participants. The authors of this study, along with team of three more researchers collaboratively developed the interview protocols around different dimensions of ISI describe earlier and components of PCK (See Appendix A). The interview protocol allowed us to understand teachers' conceptions about the each component PCK, as well as overall conceptualization towards interdisciplinary science inquiry teaching and learning. Other data sources included teachers' summer research proposals, observations of their summer research sessions and classroom instruction, and evaluations written by teachers after each professional development session. In this section, we provide details of each data source and how each data source helped us understand teachers' orientations towards ISI implementation in the classroom.

Summer research proposals. All the teachers who participated in the summer research program wrote proposals indicating their goals and outcomes from participating in this program. Based on teachers' proposals teachers were placed in different laboratories, courses and industrial setting along with a mentor to support their research proposals. We used teachers' proposals as one of the data source to understand teachers' conceptions about ISI before conducting summer research and participating in professional development programs. Teachers proposals were composed of teacher's research agenda, implementation plan, understanding of interdisciplinary science inquiry, perceived challenges of implementing ISI in the classroom, and how this experience will impact their classroom teaching. This was one of the important data source to understand teachers' overall PCK because it gave access to teachers' conceptions about ISI and teaches' envisioned before immersing in the project.

Classroom Observations. Classroom observations were another data source in this study. By observing the teachers in their own classrooms, we gained a better understanding of their teaching practices and the context in which they taught (Bogdan & Biklen, 1982). Each participant was observed for a minimum of two class periods of the classes they taught. By actually observing teachers' classroom practice and taking field notes, we were able to capture the details of how teachers act in their classrooms, which represents their PCK. In addition, our observations served as the basis for the probing questions during interview (Patton, 2002). During interview, we asked teachers to discuss their rationale and decisions surrounding the various activities they enacted during the lesson.

Interviews with Teachers. Majority of interviews were carried with the teachers after classroom observation. The purpose of conducting interview with teacher after observation was two fold: (a) to clarify the observed instruction, and (b) to explore the teacher's perceptions about the knowledge required to teach interdisciplinary science inquiry in the classroom. During interview teachers were probed to elaborate upon their thinking about choosing certain activity, resources, handouts or questioning strategy to teach interdisciplinary inquiry in the classroom. Teachers' interviews provided us rich data and allowed us to understand their thinking, reasoning, beliefs and struggles about implementing ISI in the classroom.

Professional Development Session Evaluations. We conducted professional development sessions of around three hours every month to support teachers' understanding of Interdisciplinary science inquiry around PCK framework. Some of the topics that we covered in these professional development sessions were: NGSS and common core standards overlap, instructional strategies to implement ISI in the classroom and assessment of ISI. Teachers were asked to evaluate each professional development session and were particularly asked to reflect upon what did they learn from today's sessions and their plans to implement these newly learned ideas in their classroom. These evolutions written by teachers gave us access to teachers' perceptions about the discussed component of PCK (Ex: Instructional strategies to teach ISI) and their suggestions for implementing or modifying current instruction based on this new knowledge.

Data Analysis

We employed an inductive approach to analyzing the data and in doing so began our analysis throughout the data collection process (Patton, 2002). For example, during interview teachers were asked questions related to observed classroom instruction. This information was useful to formulate questions pertinent to understanding the connections between the teachers' thoughts and behaviours. In order to analyze teachers' conceptions and orientations, we referred to four dimensions of our ISI framework. We specifically focused on understanding if and how teachers, (a) interpret and implement inquiry process skills and practices, (b) create connections within and across disciplines, (c) anchor instruction within science discipline, and (d) contextualize teaching in broader context to make it more relevant to students' lives. To understand teachers' conceptions in comparison with classroom practice we developed codes from classroom observations, interviews and other collected artifacts such as teachers' summer research proposals, classroom lesson, and field notes. We formulated codes from each data source and added new codes as the data collection proceeded. We implemented the process of constant-comparative analysis to understand teachers' thoughts and classroom practice towards each dimension of ISI (Lincoln & Guba, 1985; Patton, 2002). Three types of coding were sequentially conducted to analyse the data: open coding, axial coding, and selective coding (Strauss & Corbin, 1998). Once initial open codes were generated, we started comparing them to understand teachers' conceptions towards each aspect of PCK such as knowledge of curriculum, students' understanding, instructional strategies, and assessment and classroom teaching.

Following this same ongoing analysis process, we used the field notes, video, and interviews to develop a profile of each teacher's orientation. We started the analysis with the interviews and followed with the field and video notes. All data sources were analyzed line by line to develop an initial coding system of the how each teacher viewed the purpose of science, their role in teaching it, and the goals for student learning of science. After generating the initial codes, we grouped related codes into categories and then began developing a network of connections between the categories to understand the relationships teachers were suggesting between them.

To identify teachers' orientation', and possible shifting in their orientations, we adopted the nine categories outlined in Magnusson et al., but modified this list to include only four: traditional, activity, conceptual change, and inquiry. We added a new category in the spectrum of orientations called Interdisciplinary science inquiry. We believe in order to conduct interdisciplinary science inquiry in a classroom, along with knowledge of content and inquiry, teachers need another skillset to merge boundaries of disciplines and draw upon each other. As other researchers have noted (Friedrishsen et al, 2010) the list in Magnusson et al.'s chapter we believe is too restrictive and does not allow for multiple orientations to occur at the same time or for teachers to shift their orientation depending upon the topic they are teaching and possible barriers they are facing at the time in their teaching (e.g., equipment, time, confidence in content knowledge, etc.). Therefore, we collapsed the nine categories into four and place them along a continuum from traditional to interdisciplinary science inquiry to indicate that teachers' orientations can move along the continuum, as well as include variations of multiple orientations at different times. Figure 2 describes the five orientations we used in our study and illustrates through the use of a double-headed arrow how they compare to one another as well as the nine orientations Magnusson et al. described.

<Insert Figure 2 About Here>

In this paper we share three representative profiles; along the orientation continuum to show variations in teachers' understanding and implementation of ISI in the classroom.

Findings and Interpretation

The findings section has been divided in two areas, (a) Teachers' overall orientations and conceptions towards each component of PCK and (b) Profiles of three teachers exemplifying spectrum of orientations. To illustrate the nature of teachers' science teaching orientations at the different grade levels we developed a profile of each teacher's science teaching orientation and organized each profile according to the knowledge components of PCK (our conceptual framework). Therefore, a profile consists of a brief narrative describing a teacher's orientation toward each of the following knowledge components: (a) the purpose of teaching science, (b) science specific instructional strategies, (c) science curriculum, (d) assessment, and (e) how students think and learn science. The purpose of using profile description is to demonstrate how the individual cases form their conceptions and behavior towards teaching science according to what they know, believe, and enact in their science teaching. The presentation of the profiles and overall PCK conceptions of in-service teachers addresses both the research questions. In order to understand teachers' profiles better we have also analyzed potential contextual factors influencing their orientations.

This comprehensive analysis across the teachers' PCK towards understanding and implementing ISI in the classroom allows for a richer discussion of unique subject specific and school differences in orientations, and leads to a robust discussion of implications for professional development.

Teachers' Conceptions towards Each Component of PCK

After analyzing data it was evident teachers displayed a spectrum of understanding towards each component of PCK. We observed at least one classroom lesson for each teacher and conducted interviews with him or her. In this section we present teachers' conceptions toward ISI by implementing PCK framework. We analyze teachers' conceptions with respect to purpose of ISI teaching, instructional strategies, curriculum, assessment and students' thinking. By analyzing teachers' conceptions with respect to each component of PCK, we are hopeful to develop better insights about teachers' overall PCK and implementation of ISI in their classroom.

Teachers' conceptions toward the purpose of science teaching.

When asked about purpose of teaching ISI in the classroom, teachers' responses varied. After analyzing interviews it was evident that some teachers held broader goals for implementing ISI in the classroom, whereas some teachers focused on developing goals for their students pertinent to daily classroom activities. For example, Mr. Nare, a freshman, living environment teachers shared his goal as "*Pass this course, but I also want them to enjoy it*", whereas Mr. Cook wanted students to discover things and become "*thought provocative*" after participating in various activities. Some teachers' conceptions towards ISI teaching were reflected in their teaching and with some teachers their purpose for teaching science was not observed in their teaching. For example, Mr. Black believed that "*life is about decisions and science teaches you how to make those decisions based on evidence and I want to produce better citizens*". And in his teaching, he focused on helping students to look for evidence and base their conclusions of it. He also encouraged students to ask questions based on the activities they have experienced. Whereas Mrs. Park believed the purpose of her teaching is to help students understand inquiry process but it was not reflected in her teaching. She focused more on lecturing and hands on activities without discussing inquiry process skills and practices explicitly.

After analysis, it was clear majority of the teachers' held a goal for teaching science and implementing ISI in the classroom to make their students' college ready. Almost all teachers mentioned that the students from their classes were from intercity and probably won't go to college, but they wanted their students to be excited about science and wanted them to prepare with necessary skills, attitude and vocabulary. Mr. Maltese mentioned, "they might not go to college, but might end up working in a place where they need engineering skills and they should learn it here in the school", similarly Mrs. Beeman mentioned, "*I want to be prepared them for college. I make them write lab reports and do mini posters because I want them to see what they are going to do in the college".* Mrs. Park also held similar goal for science teaching and hence participated in this school-university partnership project to gather resources for her students. She mentioned, " *these students have never been to the university campus, they haven't visited college so taking them to campus helps them".* Through this project she planned a visit of her students to the Gross anatomy lab on the university campus. Along with college preparation, teachers also wanted students to realize the role of science in their everyday life and wanted them to develop "free minds" and see how science is around them everywhere. Few teachers also mentioned how their students lack organizational skills and study skills and through science course, they attempted to develop their students' skills to become well organized and punctual. Teachers' main goal of getting students college ready was reflected many times in the conversations during interviews as well as in their teaching. This goal also drove their instruction and reason for participating in the project to gather resources and establish connections within university, so that their students could experience real world science and understand how actual science research gets conducted.

Teachers' conceptions toward science instructional strategies. Teachers held a wide range of conceptions towards instructional strategies for teaching ISI in the classroom. Teachers' choice of instructional strategies changed based on their students' needs and available resources, but a majority of teachers preferred doing hands on activities and engaging their students with laboratory sessions. The majority of teachers who participated in the summer research projects developed some kinds of activities and lessons for engaging their students better in science. For example, Mrs. Beeman and Mrs. Nare worked together in summer to develop a gel electrophoresis lab for their students. Along with developing necessary skills these two teachers developed an outline of their laboratory session and obtained necessary materials to conduct this lab with the students. Both these teachers wanted to place this laboratory session in the larger context of their students' understanding. Along with developing students' skills to perform gel electrophoresis these teachers wanted students to understand water quality in their surrounding lake area. They designed a lab where students collected water samples from different water bodies and identified different bacteria using gel electrophoresis technique and decided water quality.

Another teacher, Mrs. Lackey who mainly worked with ESL and ELL students focused on developing students understanding of science concepts but also wanted to assist her students to develop reading and writing skills. She integrated reading and writing skills along with science concepts in the form of journals to develop her students' understanding of science. She mentioned, "*I get refugee students who can barely speak and understand English and my summer research experience opened my eyes about how to integrate different techniques to help my students develop understanding of different science concepts*". Mrs. Lackey included lot of pictorial representations in her teaching along with journaling and hands on activities. Mr. Black also struggled with students' limited reading and writing proficiency and the need to prepare them for science tests prior to participating in the summer research program. He learned a technique of incorporating white boards in his teaching. Mr. Black used white boards in his teaching for students to note down their thoughts prior to teaching a new concept, during classroom discussions and as an evaluation of concepts. According to him, this technique engaged students better and also improved their writing skills. Mrs. Cook and Mr. Maltese included science related literature in their classroom to connect classroom discussions with real world scenarios. Mrs. Cook brought simple journal articles in the classroom and sometimes posted them in the classroom for students to read and engaged them with discussions around the topic of journal article and then slowly immersed them in the science concept discussion along with hands on activities. Mr. Maltese also brought newspaper articles and other resources that talked about engineering marvels to engage his students to understand practicality of developing engineering projects in the classroom.

A majority of teachers preferred putting their students in group to develop sense of collaboration and for making them feel supported. Mr. Maltese focused on implementing project based instruction in his class where "*they can produce something and can also have fun doing it*". He focused on developing "meaningful" activities for his students to retain their interest and attention in science. Similarly Mr. Cook developed variety of microscopic slides during his summer research project and fluorescent microscopy technique to help his students see different cell organelles that cannot be seen under normal microscope. His students either worked individually or in pairs to develop cheek cell samples to identify majority cell organelles such as nucleus and mitochondria. By participating in summer research projects and professional development programs, teachers developed better understanding of different instructional strategies and believed in "doing more projects and less lecturing". Mr. Black mentioned, "*I believed in engaging students in activity first and then teaching them is better way of teaching and summer research program reaffirmed by belief".* A teacher noted in professional development evaluation, " *I learned about project based science framework and how to incorporate it in everyday lesson along with some techniques such as 5 E learning cycle*".

Another teacher mentioned, "*The "5E model" is really perfect for introducing abstract concepts and establishing relevance to students' lives".* Although a majority of teachers believed in performing hands on activities in the classroom along with some lecturing, the summer research experience and professional development support helped teachers develop better understanding of why and how to perform certain activities in the classroom in more engaging and meaningful way to make it more relevant to students' lives.

Teachers' conceptions toward curriculum. When we tried to understand teachers' conceptions towards curriculum we took into account their understanding and implementation of common core and different dimensions of ISI that we discussed in the professional development workshops. We wanted to understand teachers' perception about interdisciplinary science inquiry and how they implement this understanding in their classroom. Teachers' understanding and implementation of curriculum varied to great degrees. A majority of teachers mentioned interdisciplinary science inquiry as merging more than two disciplines in the unit. When asked during the interview about their understanding of interdisciplinary inquiry and different dimensions of ISI, many teachers replied, "*I have heard about it but I am not sure how to explain it*". Many teachers provided examples of ISI curriculum implementation in the form of examples. For example, Mr. Maltese mentioned, how he collaborates with a physics teacher to help his students develop an understanding of engineering concepts while developing projects. Similarly, Mrs. Park mentioned how she discusses different science concepts from different disciplinary points of view. A majority of teachers were aware of the need of common core standards for implementing ELA and implemented them in science context. While developing science activities, teachers kept in mind expectations of common core ELA standards. A majority of teachers also integrated different science disciplines while discussing science concepts. For example, Mr. Maltese gave an example of how he asks his students to write reports at end of each activity. He mentioned, "*I think when I ask my students to write design report; one thing I do well is incorporation of math, English and technology piece and I give them opportunity to reflect, what went well and what did not and I think that is very important*". Some teachers also believed, the purpose of common core is "to get students college ready" and they are achieving this goal by implanting different activities developed during the summer research program.

When asked about utilizing their summer research experience in the classroom, many teachers immediately answer that they were trying. Mrs. Beeman mentioned, "*I am not use to getting wrong answers. I want answers immediately and during summer research I did not get answer right first time, I did not get right answer second time, I did not get it right third time either. So it made me realize how I need to give chance to my students".* She also mentioned how she modified her questioning technique and focuses on process by asking students, "*what is the problem? How are we going to get answers? What is the plan?"* Mrs. Beeman transformed her labs, how students report it and communicate it based on her summer research experience.

Although teachers struggled with answering their understanding of different dimensions of ISI and how they implement them in the classroom, it was evident teachers were addressing one or the other dimension of ISI in the classroom if not all. While, we discussed three dimensions of NGSS with teachers explicitly, many teachers did not remember it and said, "*I have to see the document and details of it, in order to explain my* *understanding*". They also mentioned they need more support in order to develop better understanding of these different dimensions of ISI. Some teachers addressed most of the dimensions of ISI through their teaching and also transferred their experiences from summer research into the classroom; they did not feel confident about explaining how they are implementing ISI in the classroom.

Teachers' conceptions toward assessment. Teachers implemented a variety of assessment techniques in their teaching such as questioning, journaling, classroom discussions and class tests. When asked about the purpose of implementing different assessment techniques, Mr. Nare explained, " *I want to know their prior knowledge and elaborate on that knowledge and bring real world experiences. For example, lots of students have plants around them. Why do we say plants are good? Now they understand why we are talking about plants. Similarly, Vitamins give you energy, but it doesn't have calories, then how can they give energy?"* Mr. Nare asked lot of question during classroom discussion that focused on understanding students' conceptions about the science concept. Similar to Mr. Nare, Mrs. Kale also focused on different assessment strategies to help her student understand the science concepts as well as prepare them for tests. She had ESL students in her classroom, who struggled with reading and writing. Mrs. Kale used pictures for assessing students understanding. She gave example of cake and how she uses different pictures of ingredients and picture of cake for assessing her students' understanding of reactants and products. Mrs. Kale always attempted to implement assessment strategies that can be related to students' lives and will give them the opportunity to express their thinking. She always attempted to ask questions that will help her connect with students and then to their prior knowledge in order to build new knowledge for them.

Mr. Maltese invested lot of time in developing rubrics for assessing his students understanding about engineering projects. In his assessment process, along with engineering content and design, he also focused on helping students' understand the importance on reflecting on the process as well. He mentioned, "*I saw the value in students' reflection and I have adapted it, but now I give them rubric and I ask them to reflect upon specific things"*. After each project Mr. Maltese gave an opportunity to his students to reflect upon their experience and also gave them opportunity to think about weaknesses in their design and how would they fix it. In the reflection, students expressed their thoughts about design as well as their contribution in the project and how they would have done things differently with their group members. He also mentioned how he encourages students to work in-group and find answers with each others' help. He mentioned, " *My students want me to answer everything for them and I do not like that so I like them to find answers and talk to other groups. This is another thing that I do. I ask them to share their experiences with other groups, what worked and what didn't. We share before and after pictures and they share what worked and share their experiences to develop better understanding"*. Other teachers also expressed similar thoughts as Mr. Maltese about how they promote group work to enhance students' understanding of concepts and also ask questions to understand students' prior knowledge. Although, there were few exceptions to such way of approaching assessment. Mrs. Mrs. Park mentioned, she wants to understand her students' understanding about the topic, during classroom instruction; she relied on memory based questions and gave classroom test to her students.

Mr. Black, during interview explained how his instruction has changed because of summer research experience by stating,

> *I would do an activity and I use to deliver the content and let them ask couple of questions, but now I take a step back and let them go through the process and even if some of the ideas are incorrect, and work it out because it is part of the process. So now in planning I have to plan how am I going to ask those really good questions? I struggle with 'how do you ask those really good questions where focuses on phenomenon but make them ask questions about the content you want to teach. Planning part is hard and it takes time but depth of learning is greater so I am investing time*.

Similar to Mr. Black, other teachers also developed a better understanding of questioning strategies and its importance in students' learning by participating in the summer research experience. It was difficult for teachers to specifically indicate how current assessment strategies would be different from strategies that are needed for ISI assessment, they believed it would not be drastically different.

Teachers' conceptions toward students' thinking. All the teachers' expressed their views about taking into consideration students' thinking before teaching a science topic, but some of the teachers did not ask questions in the classroom that allowed students to express their thinking. For example, Mr. Wilson, while discussing topic of weather asked questions such as, "*Does anyone watch news at night? What do they call the guy that tells weather? Anyone know what knots mean?"* and continued with explaining the concept. In contrast, Mr. Nare believed in asking questions and understanding students' thinking in order to help them understand science concepts. He mentioned, " *In order to help students develop deeper understanding of concepts, you need to show them why, because and how. I want to know why did you give me that answer and what are you thinking. It might be wrong answer, but I want to know their prior knowledge".* Mr. Nare engaged students in conversation while discussing science concepts. For example, while discussing topic of nutrients he asked students, "*Are starch and sugar both carbohydrate? If they are carbs why am I calling different names?* This forced students to think about difference between terms sugar, starch and carbohydrates and its relation with each other. The responses provided by students helped Mr. Nare understand where the confusion is if any about these terms in students' minds. Similar to Mr. Nare, few other teachers led classroom discussion by asking questions.

Mrs. Kale had ESL students and she believed in discussing topics that are relevant to students' lives and helping her students make connection with the topic. She mentioned her students love topics related to genetics because they are curious about knowing how do they get curly hair and brown eye color. She believed that her students will do anything that is of their interest and hence she connected science concepts with what students already know or have experiences. For example, while discussing process of photosynthesis, she reminded them about chloroplast which they have observed under microscope the day before. This immediately reminded students about their observations about chloroplast and they participated in the discussion effectively. Mrs. Kale felt her gauging her students understanding is difficult because of their limited reading and writing skills. She continued, "*I do not think, they have understanding of different disciplines yet to understand interdisciplinary inquiry. I think I took language for granted, but language is barrier to understand my students' thinking and summer* *program made me aware about different ways to reach my kids*". She also conveyed how her students are cooperative, motivated and very willing to learn and she tried to put herself in students' shoes to be able to reach them. Overall, teachers' were aware of the need to understand students' conceptions before teaching a new topic and attempted to implement different strategies to help students express themselves. Similar to ISI specific assessment, teachers could not answer how students' thinking would be different for ISI specific topics.

Teachers' Orientations Towards ISI Teaching

From our analysis process we developed profiles of teacher's orientations towards ISI teaching. In this section, we present profiles of three teachers representing orientations along the continuum. Finally, we conclude with a cross case analysis of factors playing role in shaping teachers' orientations in the hopes of offering generalizations possibly applicable to other secondary science teachers' in order frame our discussion on the implications for professional development.

Mrs. Kale's Profile of ISI Teaching Orientations

Mrs. Kale was a freshman and sophomore teacher, teaching living environment to her students. She had four classes of ESL students and a class where a lot of students had taken biology class several times. Because a majority of Mrs. Kale's students were ESL learners, she believed in using lots of visual aids in her teaching. She mentioned, "*I cannot talk for 5 minutes and expect my students to understand it. The language is new to them and they might not have same experiences*". She mentioned, how she puts pictures for different vocabulary words to help her students understand the concept. During the interview, Mrs. Kale gave an example of how she uses visual aids and hands on activities to help her students develop an understanding of abstract concepts. She mentioned, for teaching a concept of osmosis, she brings gummy bears to the class. She puts one gummy bear in the water and other gummy bear outside as a control. This visual helps students understand the concept of osmosis. She taught a concept of hypertonic and hypotonic solutions to her students by using slat water, grapes and raisins. When Author one went to her class, she was teaching a concept of photosynthesis to her students. Mrs. Kale relied on the smartboard to show visuals to her students. During the interview she mentioned, how she loves using interactive whiteboard and how she arranges games for her students on the interactive whiteboard. During the photosynthesis lesson, she had put a labeled diagram of a leaf, water, sunlight, and Co2 written on the whiteboard. She drew her students' attention towards direction of arrow to help them understand the reaction of photosynthesis. She reminded them about how they saw chloroplast under microscope the other day. Mrs. Kale continued with asking, "*who can tell me why the chloroplast under microscope looked green?*" As lesson continued, Mrs. Kale introduced new vocabulary words to the students and also helped them understand the root meaning of the word. For example, she asked them what is the word that means color and introduced a word pigment to them. Students had whiteboards and Mrs. Kale asked them to divide the process of photosynthesis in reactants and products. Students made a T-chart and put reactants and products on the board. Mrs. Kale constantly asked questions to students and focused on understanding their thinking. As mentioned in the interview, Mrs. Kale used a lot of visual aids such as pictures on the smartboard, index cards, whiteboards and microscope to support students' learning.

When we asked Mrs. Kale during interview about her purpose of teaching science to her students, she mentioned, "*I want them to like science and they should feel it is something they can learn and do in the future*". This purpose was reflected in Mrs. Kale's classroom teaching and how she used different strategies to engage students in science learning along with developing necessary skills to perform science. For example, during the interview she mentioned how she wants her students to develop observational skills and thus uses a microscope regularly in her classroom. She mentioned, " *I want them to be observant and realize insects that look alike with naked eyes look different under microscope*". Thus she used a microscope very regularly in her classroom for her students to observe different biological specimens. She also mentioned how her students can handle microscope effectively and know different parts of a microscope. Her students also could adjust microscope and handle oil immersion slides. She also wanted her students to be ready for the exam and with limited knowledge of English her students struggled with understanding the questions in the exam paper. Mrs. Kale mentioned, how she has developed different strategies to help her students understand the questions using highlighters and marking familiar words. She used a similar strategy during classroom instruction and asked students to focus on words that were familiar to them. For example, in the classroom instruction, she asked students to find reactants and products in the process of photosynthesis. She asked them when we hear the word "process" what would it have? And students responded with "reactants and products". Mrs. Kale then asked them to find out these two things in the photosynthesis reaction.

Mrs. Kale attempted to use different strategies to help students understand science vocabulary words and retain them. During the interview she mentioned, how she connects classroom teaching with something they are familiar with and it helps them understand better. She provided an example of "cell boundary" and how she connects it with the concept of " boundary of their country". She also used examples from students' lives, so that students will be able to connect with the concept under discussion. During the summer research project, Mrs. Kale worked with group of six teachers and developed an anatomy and physiology unit, which she could not implement in the classroom this year, but the strategies which she learned during the process helped her classroom teaching with ESL students.

Considering all of this, the diagram below summarizes Mrs. Kale's science teaching orientation as interdisciplinary science inquiry oriented. Mrs. Kale promoted students' understanding of scientific concepts by integrating different reading and writing strategies and connecting those concepts with students' lives. She also integrated different scientific tools such as magnifying glass and microscopes regularly in her teaching. Unlike most of the teachers, Mrs. Kale attended a majority of professional development workshops that helped her develop better understanding of ISI framework and strategies such as project based science, learning cycle and situating science concepts in students' familiar context. Mrs. Kale had very positive summer research experience and although she did not implement the unit developed through this experience in her classroom, she implemented lot of instructional strategies that helped her connect different disciplinary core ideas.

<Insert Figure 3 About Here>

Mr. Maltese's Profile of ISI Teaching Orientations

Mr. Maltese was a12th grade teacher, teaching engineering component to students along with career and finance class to a mixed group of 10th, 11th and 12th graders. Mr. Maltese believed that students learned best when they are engaged in projects. During the interview he mentioned, "*I like to implement project based learning with my students"*. When asked why does he believe in project based learning, he replied "*because it is instant feedback. If students can produce the outcome, they have understood it"*. When Author one observed his teaching, he was working with his students to test their boomilevers. Students worked in groups of two or three. The class began with Mr. Maltese telling students the order in which they will test their boomilevers. Mr. Maltese put a setup where students adjusted their boomilevers and weighed bucket. Once bucket is adjusted, students put sand in the bucket and weighed collected sand on a scale. Mr. Maltese recorded before and after pictures of students' boomilevers. Mr. Maltese's belief in project-based science was observed in his classroom, where he encouraged students to build boomilevers. Students worked in groups and prior to building their projects, students researched the topic and planned their projects.

During summer research project, Mr. Maltese worked with two other teachers and they designed different engineering projects together. Mr. Maltese believed this experience of working with a teacher from other discipline helped him a lot because "*for long time we wanted to do this*". Mr. Maltese wanted to plan and design these kind of projects for students where they can apply and learn different physics concepts and he can learn as a student about difficulties they face while performing such activities. Mr. Maltese thought the activities which they did with the students prior to summer experience were "*scattered*" and this experience has given them "*opportunity to develop engineering components in the projects, reflect on the process and experience trials and turbulence students go through.   It was insightful*". Based on this experience, Mr. Maltese changed his evaluation with students and gave them more opportunities to reflect on the process they are experiencing and product they are building. Mr. Maltese thought these changes in the project has made his students "*motivated*" and he can provide more insights to his students to build these projects. Mr. Maltese mentioned his summer experience influenced his teaching multiple ways. He stated, " *during project building, we got frustrated multiple time while finding answers and what do we do, when we don't find answers? We research and I try to do same thing with my students*". During classroom discussion, some students' boomilevers did not work well and they felt frustrated. Mr. Maltese asked all the students to note down their reflections and then discussed these reflections with whole class. He mentioned, "*My students want me to answer everything for them and I do not like that so I like them to find answers and talk to other groups. This is another thing that I do. I ask them to share their experiences with other groups, what worked and what didn't. We share before and after pictures and they share what worked and share their experiences to develop better understanding"*. Mr. Maltese's focus on engaging students in project based instruction and giving them opportunity to experience something meaningful was expressed through his teaching.

Mr. Maltese's main purpose for teaching science was to "*build valuable lessons for his students that are meaningful for them and learn designing and manufacturing*". Mr. Maltese's purpose for teaching science was reflected in his teaching and assessment. Mr. Maltese believed, "*science is included everything and science involves everything. In* *engineering we use lot of physics and chemistry. In interdisciplinary science inquiry, it is all mesh up and very easily pass over that science knowledge into engineering*". Mr. Maltese discussed a concept of forces from physical science and explained to his students how different forces act in boomilever design and he helped them utilize this knowledge to enhance their knowledge of engineering. Mr. Maltese recorded students data in excel sheet and compiled whole class data. He told each group about how their efficiency changed from previous performance. They decided to use this data to compare different designs of boomilevers to decide the most effective design.

During the interview Mr. Maltese mentioned how he analyzes students' understanding of interdisciplinary science inquiry through giving them opportunities for reflection. Once all the students finished testing their boomilevers, Mr. Maltese gave them time to reflect upon their boomilevers, where students drew detailed sketches of their boomilevers when they tested first time (before) and second time (after). Students also noted weaknesses of their designs by specifically pointing in the design, where things can be improved. Mr. Maltese also asked about 3 major things that they will improve in the project. Students noted detailed responses reflecting different areas for improvement such as group dynamics, planning and implementation improvements. Mr. Maltese believed engineering is "*science and math together*" and hence he hardly discussed discipline specific concepts with his students. For Mr. Maltese' engineering was interdisciplinary and hence he promoted different science, math, English language arts in his classroom discussion.

Considering all of this, the diagram below summarizes Mr. Maltese's science teaching orientation as more inquiry oriented with some characteristics of interdisciplinary science inquiry. As Mr. Maltese focused on promoting science and engineering process skills and practices, discussed different science disciplinary concepts within engineering and project context with his students and also collaborated with a physics teacher to develop strong understanding of physics concepts prior to applying it with their projects display interdisciplinary science inquiry orientation. Mr. Maltese hardly mentioned during interview or classroom teaching about practical application of boomilevers or how he puts these projects in larger context that is familiar to students, but he designed effective projects for students and gave them opportunity to assess their designs and rework on them. One of the important characteristics of ISI is group-work and sharing insights and Mr. Maltese implemented this strategy effectively. Although Mr. Maltese did not attend any of the monthly professional development workshops that were focused around ISI framework, he attended other professional development programs that were mandated by the school and his teacher education program prepared him well for teaching. He admitted that some of the techniques that he implements in his class are learned during teacher training program. Mr. Maltese also had very positive summer research experience which developed his understanding about place and need for reflection to improve engineering design and also gave him insights about difficulties that students might face while performing such projects. These factors affected Mr. Maltese's understanding and teaching of ISI positively.

<Insert Figure 4 About Here>

Mrs. Park's Profile of ISI Teaching Orientations

Mrs. Park taught 7th and 8th grades living environment curriculum and has 11 years of teaching experience. Mrs. Park had a graduate student from the university assisting her classroom. Author one observed her teaching the concept of diffusion to the 7th graders. We conducted an interview with Mrs. Park after the first classroom observation. She started class by putting students in groups of four. She instructed students to listen to a graduate student, Angelina who led the session for a day. The discussion started with a question, "*who can tell me what is diffusion?*" And she answered immediately, "*movement of molecules from higher concentration to lower concentration*". Angelina, gave instructions to students about how they need to adjust a dialysis tube and follow directions given in the handout. Mrs. Park moved around and helped students if needed. During the interview Mrs. Park mentioned, "*My teaching is inquiry oriented. I prefer hands on activities and I guide my students' learning. They learn from their mistakes*". But when observed during classroom teaching Mrs. Park gave clear directions to students about how to set up an experiment and how to follow step by step instructions given in the handout. As class progressed and students started performing the instructions, one group struggled with the opening of the dialysis tube and Mrs. Park instructed in loud voice "*follow the directions*". Similarly at another occasion during interview, when asked about what different instructional strategies she implements to develop students' understanding of ISI, she mentioned, " *I conduct labs with student and I encourage discussions and questions from them*". During observations, although Mrs. Park with a help of graduate student set up and performed different laboratories to enhance students' involvement in science and give them hands on experience, she hardly encouraged discussions within small groups or with whole class. Mrs. Park insisted on maintaining a quiet classroom environment. While answering questions in the worksheet, some students struggled with the word equilibrium and tried remembering it in order to answer the question. Mrs. Park believed students might not be able to understand concepts from different disciplines well other than the one that they are focusing on in the lesson, simply because they are not familiar with it. During this lesson it was evident, Mrs. Park did not discuss how the concept of diffusion is connected with different disciplines other than how diffusion is observed in the cells, briefly.

When asked about her conception towards ISI, Mrs. Park answered, "*I always talk about connections between different disciplines. It is hard to focus on one discipline*". Mrs. Park gave an example of microscope and how she discussed a microscope from an engineers' point of view, its need for biologist, chemists' role in making stains and dyes and physicists' role in making lenses. Mrs. Park relied on giving examples while explaining ISI to her students. Although Mrs. Park spoke about the connection between different disciplines, she did not talk about the inquiry process skills and practices with her students explicitly. During the observation and interview, Mrs. Park did not discuss science concepts in relation with students' lives or connected them to the context that is familiar to students.

There was gap identified between what Mrs. Park believed about ISI teaching and learning and what she performed in practice. From these observations Mrs. Park was identified as holding a traditional orientation. During the lab session she gave clear directions to her students about what needs to be done and focused on keeping a quiet classroom environment and following directions stated in the handout. During classroom observation, some students talked amongst themselves and Mrs. Park asked them, "*what* *should they be doing while waiting?*" and student replied, "*writing the answers to the questions*" and he stopped talking with a person sitting next to him. During experiment, some students noticed change in the amount of solution in the dialysis tube and some struggled with noticing any change. As Angelina moved around the room observing and assisting students, all of a sudden she realized that she switched the solutions. Instead of putting water in a dialysis tube and different concentration solutions in the beaker, she directed students other way round. It was almost the end of the class, when she realized this and did not discuss it with Mrs. Park. Mrs. Park did not discuss with Angelina about what went well in the class and what could have been changed either.

Although, Mrs. Park's graduate student assistant Angelina, attempted to discuss some process skills explicitly such as observations and, prediction, she did not go into details of discussing these predictions and observations with whole class. Mrs. Park suggested in her responses during interview that she believed in teaching through hands on activities and inquiry but in actual practice she did not encourage students to explore things on their own or make their own observations. Mrs. Park however, did encourage students to perform lab experiments in-group as she thought they greatly support their science learning. For example, during diffusion laboratory, she put her students in groups of four and she wanted them work in collaboration and discusses concepts while answering questions on worksheet.

Mrs. Park's purpose for teaching science was mainly to make students college ready and he wanted to build confidence in her students that "*they can do it* "(Go to college). Mrs. Park took great efforts in brining different experiences and resources to her classroom so that students would get an opportunity to interact with "*real scientists*". Mrs. Park invited different scientists and graduate students from the university to interact with her students and give presentations. By giving them such experiences she was hopeful that students would be able to see scientists from different laboratories and they can "*witness*" real inquiry that might get published in the future and they can feel connected to the science.

Considering all of this, the diagram below summarizes Mrs. Park's ISI teaching orientations and how her thoughts and actions sometimes matched and sometimes contradicted. Although Mrs. Park participated in the school-university partnership project for multiple years, her understanding of ISI was limited and she did not see the need for making science teaching more interdisciplinary science inquiry oriented. Mrs. Park was one of the teachers' who did not attend any of the monthly professional development workshops that were focused around ISI framework and incorporating these components in the classroom teaching. Although, Mrs. Park made a lot of effort to bring different resources and experienced scientists and graduate students to her classroom to make science more meaningful to her students, her lack of knowledge of different dimensions of ISI made her overall teaching traditional orientated.

<Insert Figure 5 About Here>

After analyzing all three teachers' profiles it is evident that teachers can be placed on a continuum of orientations. There was clear overlap between teachers' conceptions about different components of PCK but still they held one strong orientation towards their science teaching. More opportunities for reflection and explicit discussion of ISI framework might help teachers shift their orientations toward Interdisciplinary Science Inquiry. A figure below summarizes teachers' position on orientation continuum.

<Insert Figure 6 About Here>

Role of summer research experience and professional development in teachers' orientations. All the teachers mentioned that they had benefited tremendously by participating in the summer research project or lecture series. Teachers developed laboratory sessions, activities, curriculums and resources to implement it in their classroom. Mr. Maltese worked with a physics teacher from his school to develop engineering projects for his students. He mentioned, "*planning project together is something we planned for years and this* (summer research opportunity) *allowed us to build meaningful lessons. Initially they use to go to computer and plan something, but now they manufacture things with purpose".* Mr. Maltese also added how he developed a better understanding of students' difficulties by participating in the summer research program and by experiencing the development of projects. He also admitted that the opportunity he provides for his students to reflect on the process of building projects and improving them further is something he learned by participating in the summer research project.

All of the teachers either worked in pairs or groups and they valued this experience. A majority of teachers felt grateful because they got an opportunity to learn new techniques such as Gel electrophoresis and Polymerase Chain Reaction (PCR) in case of Mrs. Beeman and Mrs. Nare and Fluorescent microscopy technique in case of Mr. Cook. These teachers felt supported by the expertise of graduate students as well as faculty members from STEM areas. These teachers also received materials they needed for their students by participating in this research project. All the teachers admitted that they developed some understanding of Interdisciplinary science inquiry because of their participation in the summer projects but they developed better understanding by participating in the monthly professional development sessions. In the one of the professional development evaluation a teacher mentioned, "*Finally began to see the big picture behind summer research. It helped me understand ISI and how to use it in our class"* Others mentioned, *" I never really thought about different dimensions of ISI before so it was helpful to understand it and it broadened my scope of knowledge"*. Teachers felt their understanding of different dimensions of ISI was " *enhanced*" and also helped them to understand "*how it can be used in my instruction and what they are composed of*". Overall professional development sessions helped teachers connect summer research experiences with different dimensions of ISI and how it can be transferred in the classroom. Our focus of developing PD sessions around PCK framework to develop teachers' ISI understanding was successful to an extent because many teachers took into account students' thinking about ISI and modified their instruction accordingly. Teachers became more aware about different components of PCK and the interdependence between these components.

A group of six-seven teachers worked together to develop a curriculum for anatomy ad physiology under guidance of two doctors. These teachers developed units around different body systems and according to their mentor's suggestion, paired systems while developing units. For example they paired circulatory system with respiratory system to develop deeper understanding of students about interdependence of these systems. These teachers developed flipcharts, Powerpoints, flashcards and other resources to address needs of their ELL and ESL students. Mrs. Kale, one of the teachers from this group mentioned, "*because of my this summer research experience, I could address my students' needs better, otherwise I would have struggled with teaching them and giving them necessary experiences and tools to support their learning*". Mr. Maltese a teacher who participated in the lecture series mentioned, "*My professor during summer class asked perfect questions that made entire conversation blossom and everyone shared their opinion and views. I actually asked him, how do you ask these perfect questions? He said it comes with time; I would love to learn to ask those kind of questions".* It was evident the summer research experience and professional development program supported overall PCK development of teachers and made them more aware about different components of PCK. Although not all teachers displayed all characteristics of inquiry and interdisciplinary science inquiry orientations, they are in the molding stage of moving towards these reform-based orientations.

Conclusion

In response to our first research question, we found all the participants developed some insight about various aspects of ISI and could relate their summer laboratory experiences or summer coursework with various dimensions of new framework. Some teachers struggled with understanding and implementing different dimensions of ISI especially crosscutting concepts because they did not see crosscutting concepts as overlap between different disciplines. Some teachers also struggled with discussing and implementing science and engineering skills explicitly with their students, but some teachers implemented them effectively. Majority teachers struggled with the fourth dimension of ISIS, i.e. drivers. Teachers did not place their projects, discussions and science topics in the context of students' familiarity and did not make it relevant to students' lives, but after discussing Project Based Science (PBS) framework with them during one of the PD sessions, some teachers could implement ISI effectively by adapting PBS framework and by integrating science, math and ELA in their curriculum. It was also evident that teachers were benefitted by summer research experiences and coursework and managed to adapt their learning experiences to a great extent to their classroom needs. Teachers felt supported with the summer experience by collaborating with their colleagues, STEM faculty members and students. These teachers also felt supported because of resources they gathered by participating in this project. Overall, teachers' conceptions towards each component of PCK were in alignment with ISI dimensions to a great extent. All the teachers displayed some characteristics of ISI orientation in their understanding and classroom instruction with the help of summer research experience, regular PD sessions and support of STEM students in the classroom.

Implications

It is evident from the analysis of these teachers' developed understanding of ISI and implemented it in the classroom because of school-university partnership support such as ISEP. Different stakeholders involved the project helped teachers develop their conceptions towards different component of PCK to implement ISI in the classroom successfully. This project provided opportunities for teachers to collaborate not only with other teachers but also expanded their horizons beyond their own schools and allowed them to seek support from university personnel to develop science content knowledge, skills, curriculum and resources. The professional development literature in science education identifies collaboration as one strategy that can be used as a means of providing professional development for practicing science teacher (Loucks-Horsley et al., 1998). As teachers specified gain in their understanding of ISI and how they felt supported through such program to implement ISI in their classroom indicates benefits of developing such partnerships between schools and universities.

Although teachers were supported with material resources and opportunities to develop necessary skills and knowledge to implement ISI in the classroom, not all teachers developed thorough understanding of different dimensions of ISI. We suggest explicit discussion of different dimensions of ISI with teachers from the beginning of the program. For example, teachers should be immersed in discussion with identifying different dimensions of ISI in their summer research project as well as activities they develop for their classroom. We suggest discussing different dimensions of ISI in explicit-reflective contextualized manner. This approach has been usually been implemented with the Nature of Science (NOS) instruction, which we believe would be successful with ISI as well (Akerson, Buck, Donnelly, Nargund-Joshi & Weiland, 2011).

We also suggest discussion of different components of PCK explicitly with teachers in order to help them identify these components in their instruction as well as how these components get integrated in their teaching. Park and Chin-Chen (2012) suggest discussing "PCK episodes" explicitly with teachers in order to help them develop their PCK. In our current study, we developed our PD sessions around PCK framework and discussed these different components of PCK in relation with dimensions of ISI. We would like to continue doing this with giving more opportunities for teachers to identify PCK episodes in their own teaching and analyzing them further.

We also suggest discussion of ISI framework in relation of NGSS and common core standards to make it more relevant to teachers' classroom. Although we discussed ISI framework in context of what was familiar to teachers such as common core standards for ELA and math, it would have been beneficial for us to draw more specific examples from these curricular documents to show interdependence, relevance to teachers' classroom to help them reveal their conceptions of ISI. This information would have helped us to modify our PD sessions to address teachers' conceptions. In the future, we would design our PD sessions with using more examples from the curricular documents and also making teachers' conceptions explicit before delivering PD content.

The final implication of our study is analyzing STEM students' role in developing teachers' conceptions towards each component of PCK to implement ISI in the classroom. Although, teachers mentioned how they felt supported with STEM students' help in the classroom in terms of supervising students' work and helping them to run classroom smoothly, it would be helpful to know if any specific component of PCK is getting more supported than other. Ex: If teachers' feel more confident in terms of their content knowledge and hence ask more productive questions or design activities and curriculum that is more interdisciplinary.

In depth analysis of teachers' orientations towards each component of PCK provided insight into how teachers need specific support in certain areas of PCK than the others in order to implement ISI in the classroom. Our findings also indicate how teachers held certain conceptions about ISI in alignment with new curriculum framework expectations but also struggled with implanting certain crosscutting concepts in the classroom, because of external factors such as available materials, support from the school and district, and expectations from external exams. Analyzing teachers' orientations towards science teaching and learning is first step towards brining change in their classroom behaviors.

References

Abell, S. K. (2007). *Research on science teacher knowledge. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp.1105-1150). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.*

Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology, 20*(5), 537-549.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Beck, J., Czerniak, C. M. and Lumpe, A. T. (2000). An exploratory study of teachers' beliefs regarding the implementation of constructivism in their classroom. *Journal of Science Teacher Education*, 11, 323-343.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, 41, 53-62.

Bogdan, R. C., & Biklen, S. K. (1982). *Qualitative research for education*. Boston: Allyn and Bacon.

Bryan, L., & Abell, S. (1999). The development of professional knowledge in learning to teach elementary science. *Journal of Research in Science Teaching*, 36, 121 – 140.

Bryan, L. A. (2003). Nestedness of Beliefs: examining a Prospective Elementary teacher's belief system about science teaching and learning. *Journal of Research in Science Teaching, 40*, 835-868.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. Berliner, & R. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 709–725). New York: Macmillan Library Reference.

Cronin-Jones, L.L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28,* 235–250.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76, 607-651.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76*(5), 493-506.

Friedrichsen, P., van Driel, J. H., & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education,* 95, 358-376.

Friedrichsen, P. J., Abell, S. K., Pareja, E. M., Brown, P. L., Lankford, D. M., & Volkmann, M. J. (2009). Does teaching experience matter? Examining biology teachers' prior knowledge for teaching in and alternative certification program. *Journal of Research in Science Teaching*, 46, 357-383.

Friedrichsen, P. & Dana, T. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations, *Journal of research in science teaching*, 42(2), 216-244.

Gess-Newsome, J., & Lederman, N.G. (Eds.). (1999). *Examining pedagogical content knowledge: The construct and its implications for science education.* Boston: Kluwer.

Hewson, P. W., & Hewson, M. G. A'B. (1987). Science teacher's conceptions of teaching: Implications for teacher education. *International Journal of Science Education*, 9, 425-440.

Hewson, P.W., & Hewson, M.G. A'B. (1989). Analysis and use of a task for identifying conceptions of teaching science. *Journal of Education for Teaching*, 15, 191-209.

Jones, G.M. & Carter, G. (2007). Science teacher attitudes and beliefs. In S.K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lantz, O., & Kass, H. (1987). Chemistry teachers' functional paradigms. *Science Education*, 71 (1), 117-134.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75). SAGE Publications, Incorporated.

Little, J.W. (2003). Inside teacher community: Representations of classroom practice. *Teachers College Record*, 105, 913-945.

Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education*, *86,* 1–22.

Loucks-Horsley, S., Love, N., Stiles, K.E., Mundry, S. & Hewson, P.W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.).Thousand Oaks, CA: Corwin Press.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge. In J. Gess-Newsome&N.G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95–132). Dordrecht, The Netherlands: Kluwer Academic Publishers.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council (NRC). (2000). *Inquiry and the National Science Education Standards.* Washington, DC: National Academy Press

National Research Council [NRC] (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academy Press.

Nargund-Joshi, V., Liu, X., Chowdhary, B., Grant, B., Smith, E. (2013,April). *Understanding Meanings of Interdisciplinary Science Inquiry in an Era of Next Generation Science Standards.* Paper presented at the annual meeting of National Association for Research in Science Teaching, Rio Grande, Puerto Rico**.**

Nargund-Joshi, V. (2012). *An exploration of the science teaching orientations of Indian science teachers in the context of curriculum reform* (Doctoral Dissertation). Retrived from ProQuest UMI Dissertations Publishing, 2012. 3554009.

National Academies (US). Committee on Facilitating Interdisciplinary Research, Committee on Science, Public Policy (US), & Institute of Medicine (US). (2005). *Facilitating Interdisciplinary Research*. National Academy of Engineering (Ed.). National Academy Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19(4), 317– 328.

Park Rogers, M., Abell, S., Lannin, J., Wang, C., Musikul, K., Barker,D., et al. (2007). Effective professional development in science and mathematics education: Teachers' and facilitators' views. *Journal of Science and Mathematics Education, 7, 507–532.*

Pajares, M. F. (1992). Teachers' beliefs and educational research. Cleaning up a messy construct. *Review of Educational Research*, 62, 307–332.

Patton, M. Q. (2002*). Qualitative evaluation and research* methods (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Tobin, K., & McRobbie, C.J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80,* 223–241.

Strauss, A. and Corbin, J. (1998). *Basics of qualitative research: techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks: Sage Publications.

Volkman, M.J., Abell, S.K., & Zgagacz, M. (2005). The challenges of teaching physics to preservice elementary teachers: Orientations of the professor, teaching assistant, and student. *Science education*, 89, 847-869.

Volkmann, M. J., & Zgagacz, M. (2004). Learning to teach physics through inquiry: The lived experience of a graduate teaching assistant. *Journal of Research in Science Teaching*, 41, 559-579.

Yin, R.K. (2002). *Case study research: design and methods* (3rd ed.). Newbury Park, Sage Publications

Zhang, B., Krajcik, J., Wang, L., Hu, J., Wu, J., Qiang, Y., et.al. (2003, April). Opportunities and challenges of China's inquiry-based education reform in middle and high school: Prespectives of science teachers and teacher educators. Paper presented at the American Education Research Association, National Conference, Chicago.

Zipf, R., & Harrison, A. (2003, April). The terrarium unit: A challenge to teachers' concepts of what is science teaching. Paper presented at the American Educational Research Association annual Meeting, Chicago.

Table 1
Breakdown of teachers' educational background and instructional experiences.

	Courses Currently Teaching	Educational Background	Teaching Experience
Name of the School	Riverplus		
Mr. Crites	Sophomores and 9-12 graders (ESL) Seniors. Conceptual Physics	Bachelors in Physics, Masters in Physics Education	8 years full time and 4-5 years of substitute teacher
Mrs. Kale	Five classes, and ESL students, Freshman and sophomore	Bachelors in Biology, Masters in Biology Education	23
Mr. Washington	Earth science to special education	Physical and Health education, Special Education, Masters in general education	
Mrs. Buck	Biology to freshman, Repeater sophomores.	Bachelors in secondary science education, Masters in education, Extra course work in Botany.	25 years
Mr. Beeman	Biology courses for Special education	Biology and Earth science Certification Masters in special education	10-12 years of Special education
Mr. Bates	Conceptual Physics. 9-12 Environmental Science	Mechanical Engineering Masters in secondary Science and Math	17 years of engineering experience, 10 years of teaching experience

Mr. Nare	Freshman Living environment	Bachelors in biology, Minor in Chemistry Masters in Education	Worked as chemist, Manager at environmental company 10 years
Mr. White		Earth science certification	
Name of the School	Harry Tech		
Mrs. Hard	Freshman	Bachelors in biology, Masters in Education	
Mrs. Yin	Seniors, biology	Masters in Education Bachelors in Botany	
Mr. Maltese	12th grade mainly and career and finance class, 10th, 11th and 12th	Machine tool and technology, Bachelors in Mathematics. Masters in career and technical education, Post bachelorette teacher education	4th Years of
Name of the School	MNS		
Mrs. Park	7th and 8th Grade, Living Environment	Masters in Education	11 years

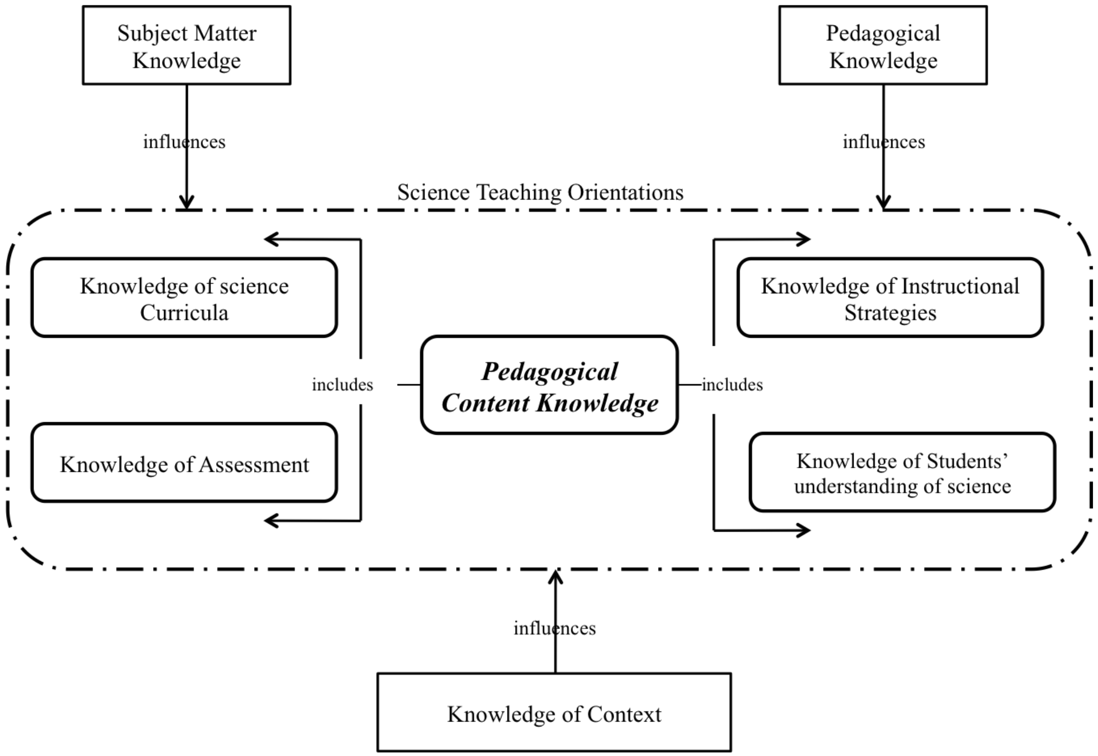

Figure 1. Theoretical framework of knowledge for teaching (Friedrichsen et al. 2009).

Nine Orientations Towards Science Teaching Described in Magnusson et al. (1999)								
Open Inquiry	Guided Inquiry	Discovery	Conceptual Change	Project-based	Process	Activity-Driven	Didactic	Academic Rigor
Goals for Teaching Science According to Each Orientation								
Represents science as Inquiry	Constitutes a community of learners whose members share responsibility for understanding the physical world. Particularly with	Provides opportunities for students on their own to discover targeted science concepts.	Facilitates the development of scientific knowledge by confronting students with contexts to explain and challenge their	Involves students investigat-ing solutions to authentic problems	Helps students develop the science process skills	Has students active with materials to provide a "hands-on"	Transmits only the facts of science	Representa-tion of a particular body of knowledge (e.g. Chemistry)

The Five Collapsed Orientations to Teaching Science Used in this Study

Interdisciplinary Science Inquiry – Teacher focuses on developing students' understanding of core science concepts along with science and engineering practices by integrating different disciplines and making discussions relevant to students' lives.	Inquiry – Teacher focuses on developing students' understanding of scientific concepts as well development of skills. Teacher guides students' learning and lead them toward open-ended inquiry.	Conceptual Change – Teacher focuses on developing students' understanding about a concept and connects it to	Activity – Teacher performs activities and demonstrations in the classroom or laboratories but focus might not be on conceptual	Traditional – Teacher focuses more on covering large amount of syllabus and focus is more on memorizing higher-level concepts than understanding them.

Figure 2. Comparison of orientations used in this study to those described in Magnusson et al. and their placement along a continuum of non-inquiry (Traditional) to inquiry-based teaching to reform-minded science teaching (Interdisciplinary Science Inquiry).

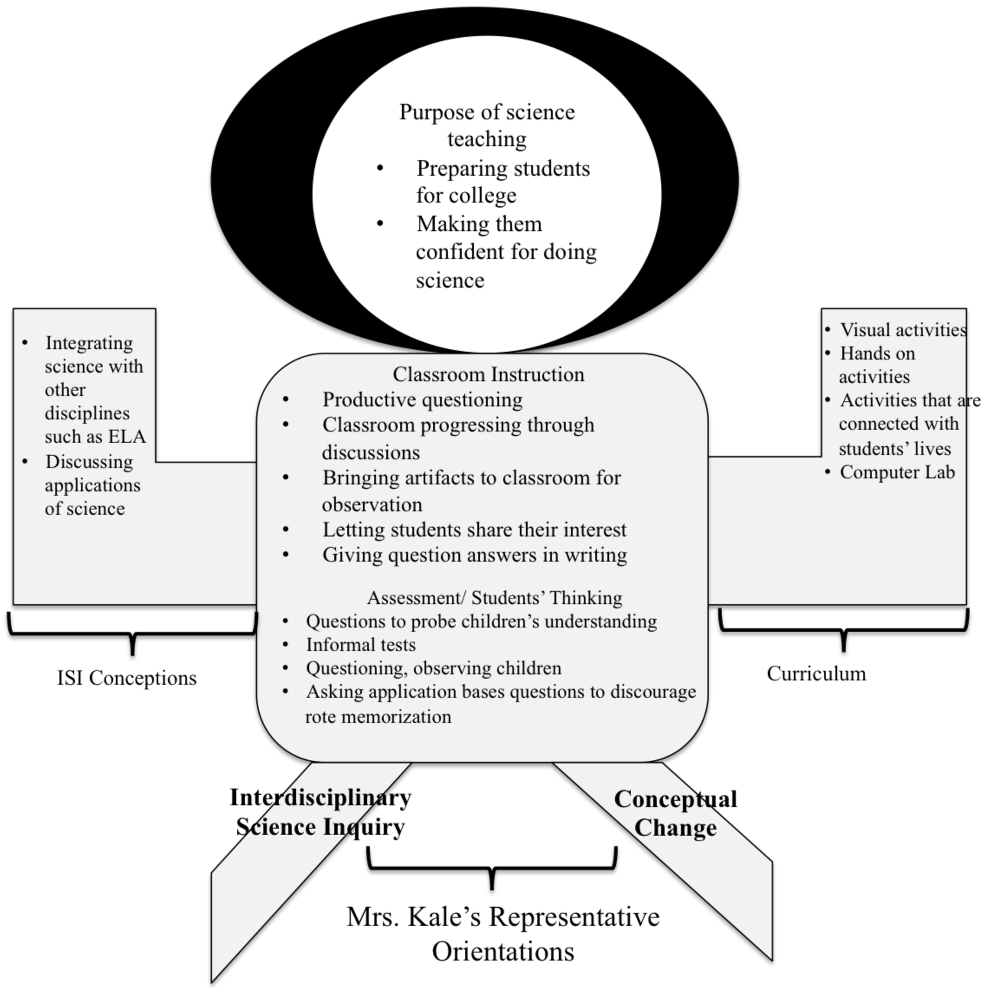

Figure 3: Mrs. Kale's Orientation toward Science Teaching

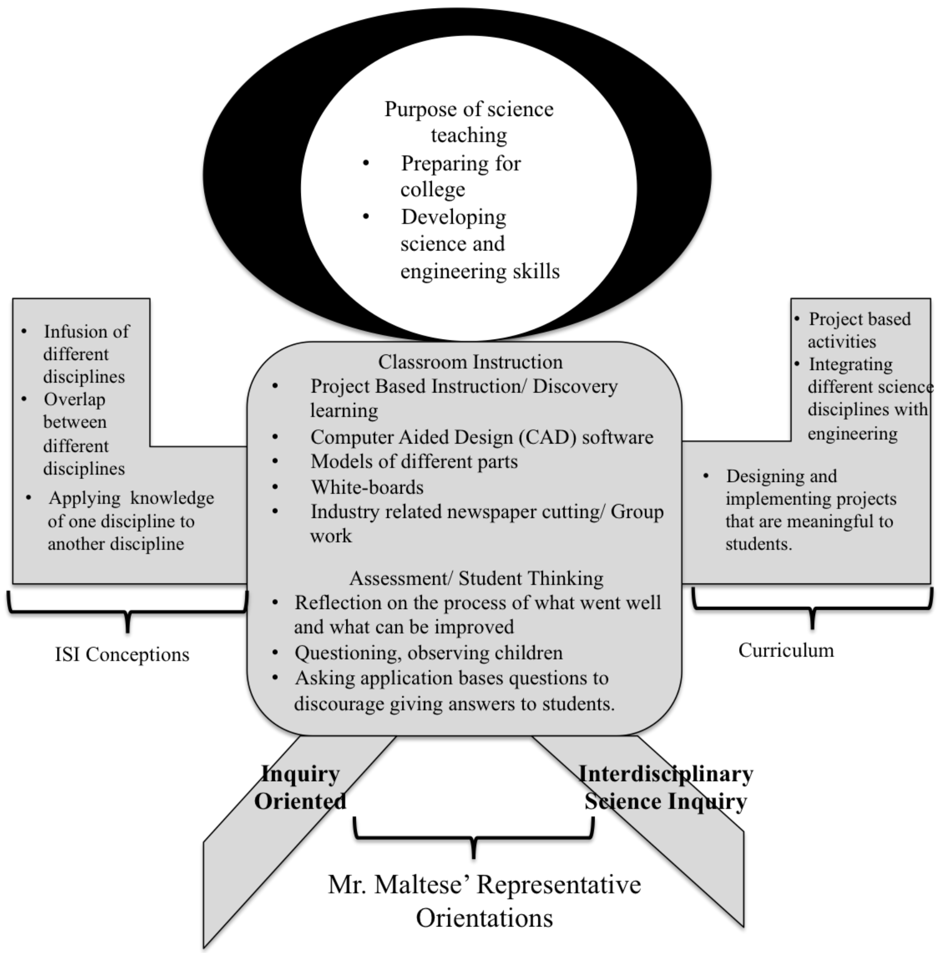

Figure 4: Mr. Maltese' Orientation toward Science Teaching

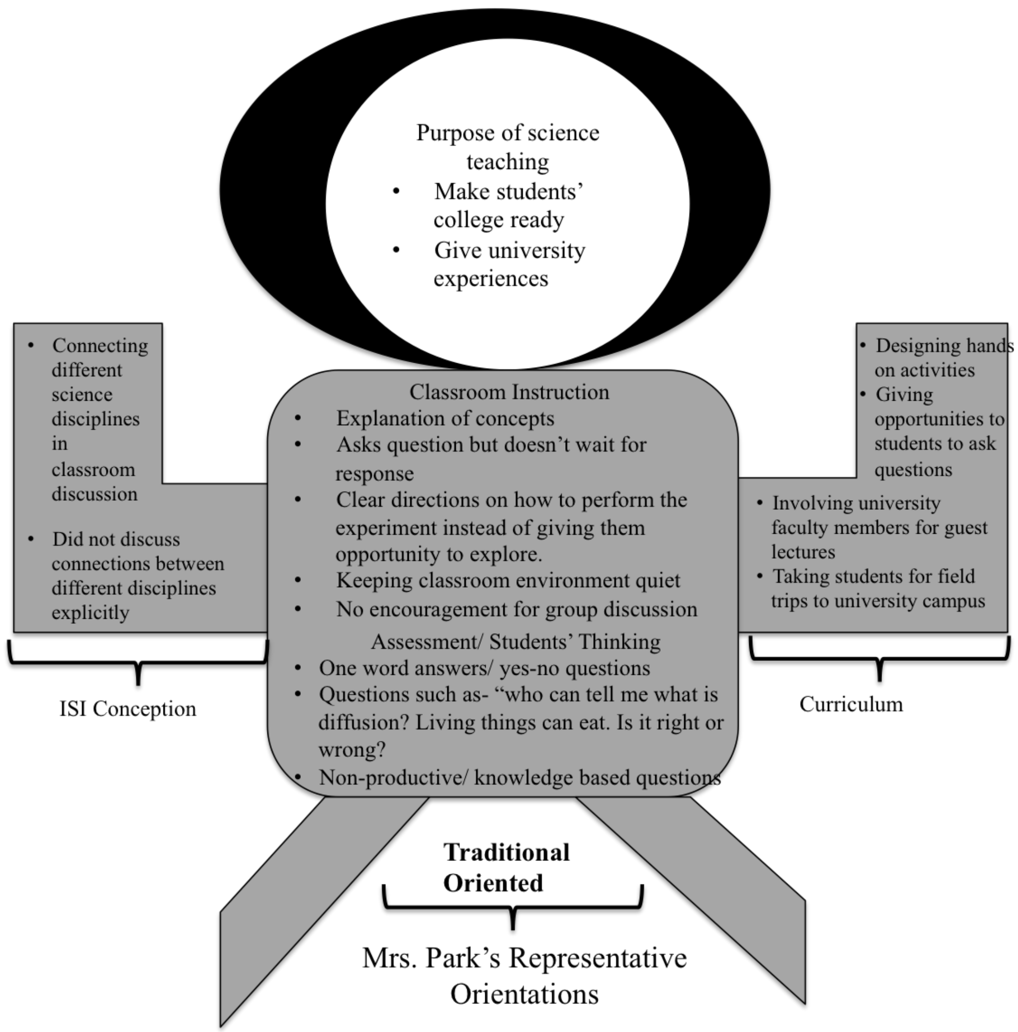

Figure 5: Mrs. Park's Orientations toward Science Teaching

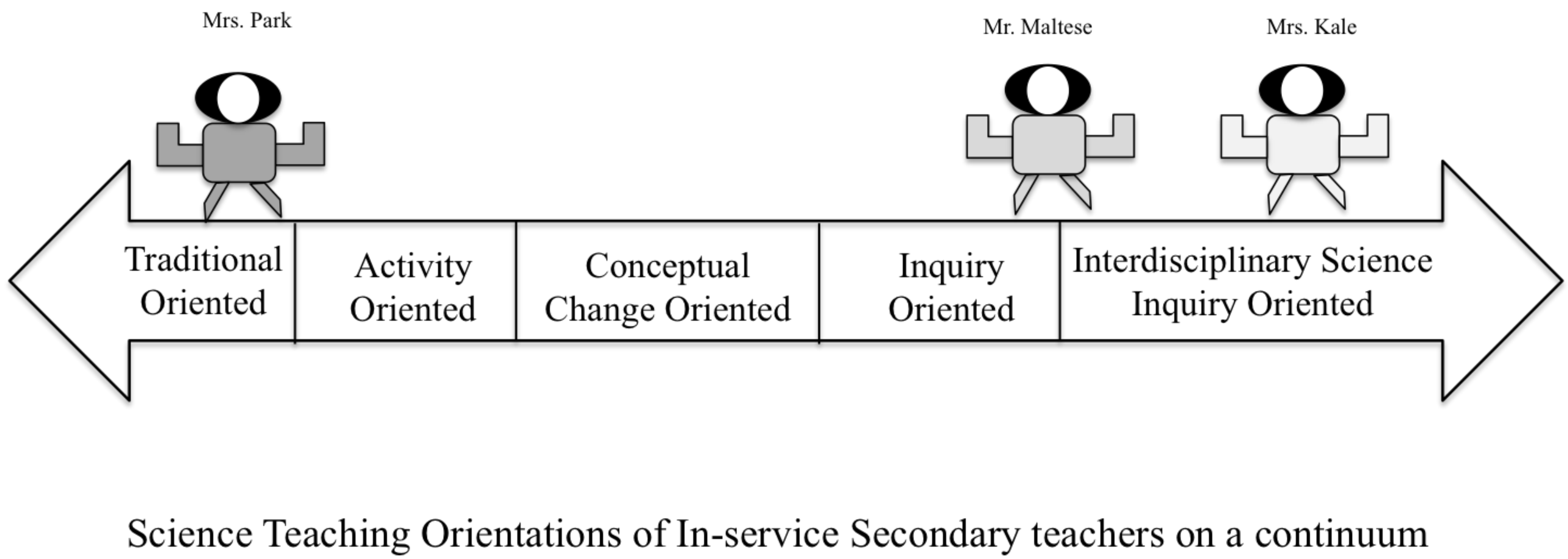

Figure 6: Science Teaching Orientations on a Continuum