**Advancing Science and Engineering in Elementary Schools:
Fostering Teachers' Knowledge and Scientific Inquiry**

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Abstract

Teachers' disciplinary content knowledge influences instructional practice. Inequalities in instruction, qualifications of teachers and resources result in widely different learning opportunities for students. To address these challenges, this Math and Science Partnership project provided 43 grade 3-5 teachers with high quality science and engineering curricula, classroom-focused professional development, and mentoring designed to address key topics in earth systems science and engineering education. The study examined whether the project's instructional activities enhanced teachers' content knowledge and further, whether the professional development improved teachers' notions of scientific inquiry. After participating in 124 hours over one year of professional development, teachers in the project group showed significant increase in content knowledge in earth systems science and related engineering concepts compared to teachers in the comparison group. Their notions of scientific inquiry improved after attending a two-week summer institute. However, PISA teachers' description of the inquiry process was not nearly as complete or elaborated on the post-survey compared to the pre-survey. Moreover, teachers struggled to accept the new concept of model-based inquiry, suggesting that the experiment-driven inquiry framework is deeply ingrained in their science teaching orientation.

Introduction

In today's changing global economy, science and technological literacy are crucial for students to compete in the 21st century (Committee on Prospering in the Global Economy of the 21st Century, 2007; Biological Sciences Curriculum Study, 2006). The widening gap in achievement and low interest in science, engineering, and math between students in the U.S. and those in other developed countries are major concerns. In 2000, 93% of students in grades 5-8 in the U.S. are being taught by teachers who are lacking the qualifications, content knowledge, and pedagogy to teach science, engineering, and mathematics (Committee on Prospering in the Global Economy of the 21st Century, 2007). Moreover, teachers have little familiarity with either science inquiry or engineering design process, and may not have developed the instructional strategies needed to facilitate student inquiry and engagement in the engineering design process (Committee on K-12 Engineering Education, 2009). To address these concerns, the Commission on the Skills of the American Workforce recommended to recruit, retain,

educate, and to provide professional developments to teachers, particularly in elementary and middle schools, in science, technology, engineering, and mathematics (STEM) disciplines (National Center on Education and the Economy, 2007).

Teachers play a major role in the classroom. They have the ability to create and mold the environment where students can learn (Shulman, 1987). Moreover, teachers' disciplinary content knowledge can have influence on instructional practice (Gess-Newsome & Lederman, 1995; Sanders, Borko, & Lockard, 1993). Unfortunately, inequalities in instruction and qualifications of teachers and resources result in widely different learning opportunities for different students (Duschl, Schweingruber, & Shouse, 2007).

To address the challenges mentioned above, the Partnership to Improve Student Achievement (PISA) provided 43 grade 3-5 teachers in New Jersey with research-based science and engineering curricula, classroom-focused professional development, and classroom mentoring designed to address topics in key content areas in science and engineering education. This is a three year project (2007-2010) funded by the N.J. Department of Education's Math and Science Partnership program. This paper will discuss data collected and analyzed on the second year of the three year program. Scientific inquiry and the engineering design process were two of the vehicles used in the professional development activities to promote teachers' content and pedagogical knowledge and increase students' achievement and engagement in science. The partnership included six urban districts in northern N.J., an engineering university, a science center, and a teacher education institution. Teachers received 124 hours of professional development, including a two-week summer institute, monthly classroom support visits (coaching, modeling, curriculum alignment, and planning), and three full day professional development workshops during the school year. Our research questions were: (1) do the instructional activities in the project enhance teachers' content knowledge in specific science topics and engineering and (2) do these activities help improve the teachers' notions of scientific inquiry after one year of intensive professional development? Data analyzed for our findings include pre- and post- tests of science content in earth sciences and three inquiry surveys administered to teachers in 2008-2009.

Each year of the PISA program has focused on a different science discipline with corresponding technology and engineering lessons. Elementary teachers who participate in all three years of the program are exposed to higher level content knowledge in each of these science disciplines. Year one was devoted to life and environmental sciences; year two to earth and space sciences; and year three to physical sciences. During the two-week summer institute that was held in 2008, teachers learned earth and space science content through a sequence of science and engineering investigations presented by faculty and instructors of the engineering and teacher education colleges. These investigations were developed using a backwards-design approach (Wiggins & McTighe, 2005) based on content foci presented in the New Jersey Core Curriculum Content Standards (2004), the National Science Education Standards (National Research Council, 2000), and the New Jersey Assessment of Skills and Knowledge (NJ ASK), a statewide science assessment. Sample science lessons included Phases of the Moon, Reasons for Seasons, Classifying Rocks and Minerals, and Correlating Fossil Evidence. In addition, model-based inquiry was a guiding framework (Gilbert, & Boulter, 1998; Crawford, 2004) of the professional development. Model-based inquiry instruction is a form of inquiry that emphasizes the role of

models in scientific practice, in particular, the use of models to build, revise and argue about scientific knowledge. Successful teaching of inquiry, model-based or otherwise, is challenging for most teachers, particularly preservice teachers (Schwarz & Gwekwerere, 2007; Windschitl & Thompson, 2006).

For instance, teachers reviewed and learned "the reasons for seasons on Earth" by drawing their expressed models, using physical models (Styrofoam balls), and explaining how the different seasons occur on Earth. Using their prior conceptions that were expressed in their initial models; they went through series of lessons using physical models, computer models, experiments, and expert's perspective (guest professor). At the end of the lesson, they revised their initial models and presented their consensus revised model in front of the class that best explained their groups' expressed models (see Figure 1). After a series of model-based inquiry lessons, teachers

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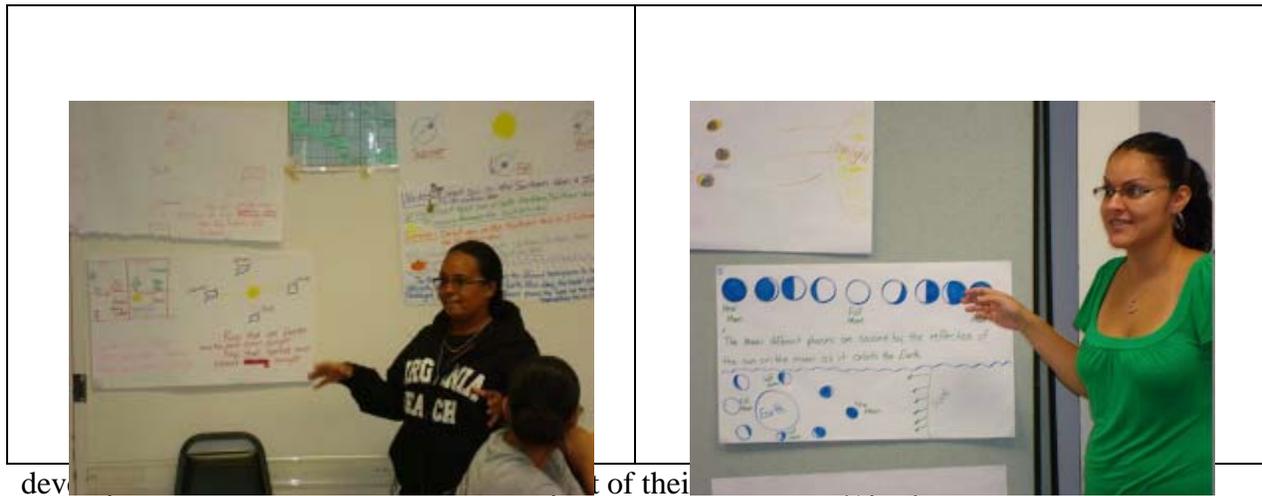
Figure 1- Teacher presentations

In addition to science inquiry, teachers investigated two *Engineering is Elementary (EiE)* modules (Museum of Science, Boston) during the summer institute to learn the engineering design process. In the engineering design process, the learners engage in asking questions, imagining possible solutions, planning, creating, and improving designs to solve a problem (Lachapelle, 2007). The first module was *A Sticky Situation* where they learned about different earth materials and designed their own walls. The second module, *Catching the Wind, teachers* studied weather and designed their own windmills. A scientist helped teachers in their understanding of earth materials and their properties. Teachers then applied this knowledge to the creation of their own mortar for walls they constructed (see Figure 2). Another professor showed them how wind can be measured and how it can be used for energy.

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Classifying Rocks and Minerals	Designing Walls

Figure 2 Field trip and applying the engineering design process

Classroom support visits were another component of the program intended to ensure success of the teachers in implementing what they learned over the summer in their classrooms. Visits were also used to document and assess the needs of teachers and students. The three workshops conducted during the school year reinforced and expanded the science content knowledge that teachers learned during the summer institute. PISA aims to address the challenges presented by the *Rising Above the Gathering Storm* report which recommends teacher educators, researchers, and policy makers help teachers improve the quality of science, technology, and engineering education in the U.S. and better prepare students for the 21st century (Committee on Prospering in the Global Economy of the 21st Century, 2007).

Background

Exemplary professional development is needed to enhance teachers' content knowledge and pedagogical content knowledge in science and engineering (Committee on K-12 Engineering Education, 2009). We hypothesized that through the instructional lessons in the workshops, which were designed to promote scientific inquiry and the engineering design process, teachers' content knowledge and classroom practices would be enhanced (Kennedy, 1998).
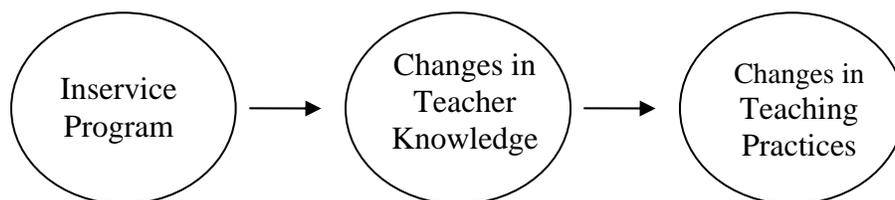
In this section, we will present a brief review of the literature that illustrates the different features of the PD program that contribute to an increase in teacher knowledge and teaching practices as

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well as the challenges encountered in helping teachers develop a reform-based approach of teaching science and engineering.

Professional development enhances knowledge and classroom practices of teachers. Ingvarson, Meiers, and Beavis (2005) conducted a survey of 3,250 teachers who participated in 80 individual PD studies. The review of research studies aimed to identify exemplary models and characteristics of effective PD programs. Findings suggested that the program's content has the most impact on teachers' knowledge. Follow-up workshops also contribute to knowledge gains. In terms of factors that influence teachers' classroom practices, programs that provide many opportunities for active learning and reflection on practice top the list. Finally, when looking at impact on knowledge and practice together, the significance of a professional community became apparent.

Teachers improved their knowledge and practices of scientific inquiry after attending preservice and inservice programs. Model-based inquiry is an instructional approach in which learners engage in scientific inquiry whose focus is on the creation, evaluation, and revision of scientific models used to understand, explain, test, and/or predict parts or characteristics of the natural world (Lehrer & Schauble, 2006; Schwarz, 2009; Windschitl, 2008). It is different than the traditional scientific method – making observations, defining the problem, constructing hypotheses, experimenting, analyzing results, and drawing conclusions - because questions are derived from a model that represents the observable (e.g. balloon expanding) or unobservable (e.g. collision of molecules inside the balloon) world/phenomenon and not based on what is interesting or doable (Windschitl, 2009). In the process of modeling, students are able to create investigations based on the model; and construct, test, and revise their own model according to the results of their experimentations, rather than following cookbook procedures or conducting simple investigations that are based on comparing and contrasting variables (Chinn & Malhotra, 2002). Moreover, modeling allows teachers to elicit students' alternative conceptions, anchor the lesson on these conceptions, develop experiments based on the model, monitor students' progression of learning, and promote data-driven argumentation (Schwarz, 2009).

Research studies in model-based inquiry had mixed successes. Crawford (2004) used dynamic computer modeling, *Model-IT*, to support 14 secondary preservice science teachers' conceptions of modeling in science. After one semester of engaging in modeling experiences, designing open-ended investigations, and building and testing their own dynamic computer models, the preservice teachers became more articulate in their language of modeling, and the computer modeling fostered their ability to think critically about mechanisms involved in modeling. In the multi-case study of Windschitl (2004) with 14 preservice teachers enrolled in a secondary science methods course, participants shared their own framework of what it means to do science. Analysis of journals, interviews, inquiry projects, and supervisor's observations revealed that participants held a limited view of scientific inquiry. Specific examples of participants' understandings included: "hypothesis functions as a guess about an outcome, but not necessarily part of a larger explanatory system," "that the background knowledge may be used to provide ideas about what to study but the knowledge is not in form of a theory or a model," and "a theory is an optional tool one might use at the end of a study to help explain results (p.491)." According to Windschitl (2004), these ideas appear consistent with a folk theory of doing science, which don't reflect the authentic science. Justi & Gilbert (2002) studied 39 Brazilian

elementary and secondary teachers in their knowledge about and attitudes towards the use of models and modeling in learning science. Based on teacher interviews, teachers had limited views of models and its use in the classroom. Specifically, the majority of teachers thought that models were used to explain scientific thoughts to students, teachers did not seem to realize the difference between scientific/historical models and teaching models, and teachers thought that they were incapable of working with students' expressed models. In Macalalag & Duncan (2010), 15 preservice teachers improved their ability to design inquiry-based lessons after attending four methods courses in Biological Sciences. Analysis of lessons revealed growth in the teachers' ability to: (a) craft appropriate questions to gather students' preconceptions and drive inquiry lessons, (b) anticipate students' prior knowledge and attend to the broader context of the curriculum, and (c) create more relevant investigations.

Teachers increased their knowledge and experience to incorporate engineering education in the classroom after attending PD programs. The majority of teachers, especially in the elementary schools, lacked the knowledge and pedagogy to teach engineering in their classrooms (Committee on K-12 Engineering Education, 2009). The engineering design process involves learners in asking questions, imagining possible solutions, planning, creating, and improving designs to solve a problem (Lachapelle, 2007). Unlike scientific inquiry that is focused on construction, testing, and revision of models, the engineering design is focused on the design, testing, and redesign of a product or a system. Hynes and dos Santos (2007) designed a PD study to prepare thirteen middle school teachers in Massachusetts to teach an after school engineering/technology robotics unit. The majority of the teachers in the study did not have any formal training in teaching engineering/technology before joining the program. Research findings suggested that the two-week PD was successful in improving teachers' confidence in their knowledge and in teaching engineering principles. Teachers benefited from the program by engaging in multiple hands-on opportunities with the materials, practicing teaching the engineering lessons in a safe environment afforded by the program, and by learning from other teachers. Carson and Campbell (2007) reported that the 24 elementary teachers improved their instructional behavior towards engineering after attending summer workshops. Specifically, teachers included more engineering examples, concepts, career information and problem-solving strategies in teaching science and mathematics. In the study conducted by Macalalag, Brockway, McKay, and McGrath (2008) on the first year of the PISA program, 57 grade 3-5 teachers' and students' improved their content knowledge in science and engineering after a year of PD. Finally, the study of Lachapelle (2007) with about 400 grades 3-5 students in 12 schools in New Jersey showed that students improved their understandings of engineering and technology after participating in engineering design activities. The post-assessment revealed that elementary students' demonstrated a much clearer understanding of: (1) technology as human-made-regardless of whether it is modern or uses electrical power, (2) the work of engineers as involving design and teamwork- not everyone who works with engines or electricity is an engineer, (3) engineering as a career, and (4) the science content.

In this brief review, we described the different features of PD that influenced teachers' and students' content knowledge. In our PISA program, we provided a two-week summer institute and three follow up workshops over one year of a three-year program. These were part of 124 hours of intensive PD aimed at providing teachers with increased understanding of targeted science and engineering concepts through active learning, specifically through science inquiry,

engineering design, and reflection. We hypothesized that PISA teachers' content knowledge would increase similar to what Ingvarson, Meiers, and Beavis (2005) found due to the intensive PD. Given the findings of Crawford (2004) and Macalalag & Duncan (2010), we predicted that teachers' notions of scientific inquiry and ability to design inquiry-based lessons would improve as a result of the two-week workshops. However, we anticipated that teachers would struggle in this new concept, as they teach and implement inquiry-based lessons in their own classrooms, similar to findings of Windschitl (2004) and Justi & Gilbert (2002.). Finally, we predicted that the PISA teachers would improve their knowledge and instructional behavior towards implementing the engineering design process after a year of PD similar to the findings of Campbell (2007) and Macalalag, Brockway, McKay, and McGrath (2008). In the next sections, we will describe our methods, data sources, analyses, and findings.

Methods

The year two PISA summer institute was held in July and August 2008. Of the 49 PISA teachers who participated in the first year of the project, 6 left during the school year, resulting in 43 remaining from year 1. PISA teachers taught students in grades 3-5 from 18 public and 3 non-public schools in northern N.J. PISA teachers included classroom teachers, inclusion teachers, special education teachers, and a computer technology teacher. In September 2008, a comparison group of 35 teachers was selected and matched against the PISA group of teachers based on the school's geographic location, demographics, grade level, and subjects being taught.

A single instrument for pre- and post-tests was developed and administered to PISA and comparison teachers to assess content knowledge in specific earth and space science topics, and understanding of the engineering design process. Questions were selected from the available questions published online by the Trends in International Mathematics and Science Study (TIMSS), Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART), Praxis Test Prep Materials, A Private Universe Project, and items developed by the Museum of Science in Boston. Pre-tests were given to PISA teachers on the first day of the summer workshop and were administered individually to comparison teachers in September 2008. Both groups of teachers received their post-test in May 2009.

A survey was developed to capture changes in the teachers' notions of scientific inquiry over one year (see Appendix A). The instrument was adapted from a survey about teachers' ideas about doing inquiry science in the classroom developed by Dr. Anne Rivet, Assistant Professor of Science Education at Teachers College, Columbia University, Windschitl, (2004), and the National Science Education Standards (National Research Council, 2000). The inquiry surveys were given to PISA teachers on the first day of the 2-week summer institute, last day of the institute, and end of school year. The survey was also given to teachers in the comparison group, once at the end of the school year.

Results

Teachers' Content Knowledge in Specific Earth and Space Science Topics and Engineering

The pre-test for PISA teachers was administered at the beginning of the summer institute and the pre-test for the comparison group of teachers was administered at the beginning of the fall semester. Both groups had their post-tests administered at the end of the spring semester 2009.

Before looking at the improvement at the end of year on the basis of post- test scores, we examined whether the PISA group and comparison group teachers had the same baseline knowledge. A T-test was performed to compare the mean pre-test scores of the PISA group teachers and that of the comparison group teachers. Though the PISA group had a slightly higher mean score (M=16.12, SD=3.033) than the comparison group (M=15.17, SD=3.294), there was no significant difference between the two group's mean scores (t(76)=1.316, p=.192>.05). After establishing the baseline, the next question we asked was whether each group of teachers showed improvement from the pre- test to post- test and if there was a difference in outcome for the group that participated in a year of professional development. When looking at each group separately, the PISA group showed a significant increase in their test scores of science and engineering, from 16.11 in the pre-test to 18.27 points in the post-test (t(36)=-3.991, p<.01), while the comparison group had virtually no increase, from 15.33 to 15.73 points (t(32)=-0.707, p=.485>.05).

Although it would appear from the previous analysis that the PISA group improved significantly more than the comparison group, an analysis of covariance (ANCOVA) was used in order to control for differences in pre-test scores. The ANCOVA without the interaction component showed that the difference in post-test scores between the two groups was significant (F(1,67)=8.846, p<.01) when the pre-test scores are held constant. In other words, the PISA teachers' post-tests scores improved significantly even when their slightly higher pre-test scores are taken into account.

Out of the 26 test questions, 22 were science questions and 4 were related to the engineering design process. We analyzed these scores separately to ascertain teachers' content knowledge in science and engineering. The analysis showed that for science questions, the mean scores of PISA group teachers increased significantly from 13.51 in the pre- test to 15.05 points in the post- test (t(36)=-3.414, p=.002<.01). The comparison group showed virtually no increase. Analysis of covariance (ANCOVA) was used in order to control for differences in pre-test scores of both the groups. The ANCOVA showed that the difference in post-test scores between the two groups was significant (F(1,67)=7.197, p=.009<.01) when the pre-test scores were held constant. In another words, the PISA teachers' post-test scores improved significantly even when their slightly higher pre-test scores are taken into account.

We saw similar results on the questions specific to the engineering design process. The PISA group showed significant increase in their test scores, from 2.59 to 3.22 points (t(36)=-2.698, p=.011<.01) and the comparison group showed virtually no improvement.

	All Questions	**Science only**	**Engineering only**
Did the experimental group teachers have significant increase in their test scores?	Yes	Yes	Yes
Did the comparison group teachers have significant increase in their test scores?	No	No	No
Did the experimental group teachers perform significantly better than the comparison group teachers?	Yes	Yes	Yes

Figure 3. Summary of results (teachers' pre- and post-tests)

Teachers' Notions of Scientific Inquiry in Pre-survey

Workshop instructors were asked to rate the teachers' levels of competence (high-moderate science content knowledge, some science knowledge, little or no science knowledge but willing to learn, and no science knowledge) because it seemed likely that teachers' levels of competence would correlate with the extent to which they considered their classroom inquiry-based. The first question on the survey asked to what extent the teachers felt their science classrooms could be described as inquiry-based classrooms. Almost 50 percent felt that this was only "somewhat" the case. However, there was no statistical correlation between the instructor's rating of the teachers' competence as science teachers and the teacher's rating of their classrooms as inquiry-based. However, it is noteworthy that those with little or no science knowledge were more likely to see their classrooms as inquiry-based than those with more knowledge (see Figure 4). In addition, there was no correlation between the teachers' years of teaching experience and their ratings of their classrooms as inquiry-based.
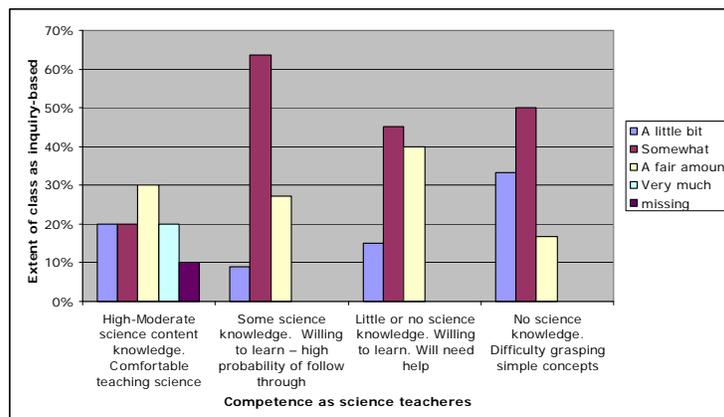
Figure 4. Teachers' competence level vs. Extent of class as inquiry-based

The survey asked the teachers to indicate the ideal frequency (most of the time, a lot of time, limited amount of time, and never) during which they would like their students to participate in science inquiry activities and compared the results to the actual frequency that these activities were done by teachers. Results indicated that the majority of teachers felt that they need to change the way they teach to make their classroom more inquiry-based. Specifically, they

wanted to do more of the following with students: brainstorming in the beginning of a unit, reflecting on their own work, making thinking visible through models and modeling, making sense of data, sharing ideas with others, and using evidence to support their conclusions. There was only one item in which the majority of teachers felt that they did not need to change and that was "students working individually."

In the question: "In your own words, describe what a science class is like when students are doing inquiry," teachers' answers to this question fell into three major categories- the format of the class, the source of inquiry question, and the process of scientific inquiry. Over two-thirds of the teachers (69 percent) did not specify the format of the class. Most of the remaining teachers (29 percent) described the ideal class as working in groups. Sample responses included:

"I envision inquiry in a science class as children engaged in small group discussion."

"Students…are in groups and they are discussing and sharing ideas with one another."

Only one person said it could be either in individual work or in group work and none described individual work. Many of the teachers (46 percent) also included descriptions of the students' interactions with each other in the class:

"…brainstorming together, discussing/ working together."

"The students are quiet first. Later, when an idea comes out and contradiction gets it, the class becomes interactive…"

There were six codes generated for the source of inquiry question. They were teacher generates question (guided inquiry), students generate question (independent inquiry), both guided and independent inquiry, unspecified who generates question, implies a question, and no question. About one-third of the teachers (33 percent) wrote that the students would generate questions for the inquiry.

"Students…asking questions to themselves or to the other students to find the best solutions"

"…they're asking questions and trying to use any prior knowledge"

"Students are forming their own questions about a particular science topic, and then designing investigations of their own."

Only a few teachers (6 percent) wrote that the questions would be generated by the teacher, by both teachers and students (4 percent), and about one-quarter (24 percent) did not specify who should generate the inquiry question (see Figure 5).

Coding Scheme	Count	Percent (n=49)
Teacher generates question (guided inquiry)	3	6%
Students generate question (independent inquiry)	16	33%
Both guided and independent inquiry	2	4%

Unspecified who generates question	12	24%
Implies a question	4	8%
No question	12	24%

Figure 5. Sources of inquiry questions (Pre-survey)

Based on the model response generated by one of the project instructors, the process of scientific inquiry was broken into ten steps (see Figure 6). Only a few teachers (14 percent) came close to including the first step (A), where students generate naïve models as part of the process of scientific inquiry. However, they were generally referring more to eliciting prior knowledge than to generating actual models. One-third (33 percent) included students developing hypotheses that can be tested experimentally (B). About half of the teachers (53 percent) included the idea that students will conduct a series of observations or experiments using different techniques or approaches (C). Only a very few (4 percent) included students analyzing data (D) and wrote that they would explain the results based on science (E). None of the teachers mentioned the final parts of the inquiry process: (F) students revise models, (G) students present a consensus model, (H) students conduct additional experiments, (I) students further revise the model, or (J) students present final model. When combinations of steps in the inquiry process were analyzed, we found that the most commonly listed step (C—observations/experiments) was most frequently combined with B (developing hypotheses), and less frequently with A (generating naïve models) and D (analyzing data).

Coding Scheme	Count	Percent (n=49)
Students generate naïve models (A)	7	14%
Students develop hypotheses to test experiments (B)	16	33%
Students conduct a series of observations or experiments, using different techniques or approaches (C)	26	53%
Students analyze the data (D)	2	4%
Students explain results based on science (E)	2	4%
Students revise models (F)	0	0%
Students present consensus model (G)	0	0%
Students conduct additional experiments (H)	0	0%
Students further revise the model (I)	0	0%
Students present final model (J)	0	0%

Figure 6. Processes of scientific inquiry (Pre-survey)

A follow-up open ended question in the survey asked the teachers to describe the reasons that they felt were most responsible for the discrepancies between the ideal and actual amounts of time they had reported in terms of teaching science. Teachers' responses to this question fell into 5 categories and the categories were: student population, time and test prep issues, limited resources, curriculum-related challenges, and policy/leadership expectations. Teachers' perceived challenges related to student population included different ability-levels of students, behavioral/discipline problems, not used to scientific inquiry, lack of collaborative working skills, special education students, class size, and lack of parental support. Time and preparation were described as a result of standardized exams and districts' curricula that were focused in

language arts and mathematics. Limited resources included money, materials, space, and support. Curriculum-related problems were limited, outdated and difficult science curriculum curricula. Lastly, teachers received a variety of support and expectations from their schools' administrators.

Teachers' notion of scientific inquiry after the summer workshops

The question on the second survey asked the teachers to describe the process of scientific inquiry. Since this question did not ask them to describe a class, the organization of the class was not included in the analysis of the responses. The other two categories were the same as in the analysis of the first question- the source of the inquiry question and the process of scientific inquiry.

We used the same six codes for the source of the inquiry question (see Figure 8). In this case, about the same number of teachers (17 percent) wrote that the questions were mainly generated by the teacher and 15 percent wrote that they were mainly generated by the students. Only a very few teachers (6 percent) wrote that questions were generated by both the teacher and the students and many teachers (34 percent) did not specify who should generate the inquiry question.

"Inquiry is when a question is presented."

"The process of inquiry starts with a question about known concept or process.…"

Several teachers (4 percent) gave answers that were ambiguous in terms of whether a question was involved. Even after several days of discussing inquiry, almost one-quarter (23 percent) of the teachers did not include any mention of questions. Instead, they focused on a different phase of the inquiry process, this time with more reference to the preceding phase of modeling, which had been discussed at length during the workshop, as well as the subsequent phases of observing and experimenting:

"Scientific inquiry begins with the creation of an initial model."

"Scientific inquiry allows students to 'do' or 'discover' science, rather than simply listen to or read about science."

Coding Scheme	Count	Percent
Teacher generates question (guided inquiry)	8	17%
Students generate question (independent inquiry)	7	15%
Both teacher and students generate questions	3	6%
Unspecified who generates question	16	34%
Implies a question	2	4%
No question	11	23%

Figure 7. Sources of inquiry questions (survey after two-week summer workshops)

Regarding the process of scientific inquiry, the same steps were used in the analysis. The numbers and percentages were as follows:

Coding Scheme	Count	Percent
Students generate naïve models (initial conceptions) (A)	25	53%
Students develop hypotheses to test experiments (B)	4	9%
Students plan investigation I	4	9%
Students conduct a series of observations or experiments, using different techniques or approaches (D)	39	83%
Students analyze data (E)	7	15%
Students explain results based on science (F)	11	23%
Students revise their models based on data (G)	20	42%
Students present consensus model (H)	10	21%
Students conduct additional experiments (I)	4	9%
Students further revise the model (J)	3	6%
Students present final model (K)	1	2%

Figure 8. Processes of scientific inquiry (survey after two-week summer workshops)

In this response, a much larger percentage of teachers (83 percent) focused on having students conduct a series of observations or experiments, using different techniques or approaches (D):

"Children…answering questions through scientific experiments, research of data, etc."

"The child will then proceed to observe, gather data, and explain."

"Scientific inquiry is the process by which students are constructing knowledge …through…hands-on activities."

"It is discovery learning that is student directed through the use of models (physical, visual, etc.) Scientific inquiry drives content and scientific practices like observations…"

A much larger percentage of the teachers (53 percent) than on the first survey also included the step where studentsgenerate naïve models (A). In addition, although there continued to be some confusion between eliciting prior knowledge and actually constructing a model from that knowledge, the word "model" was used much more frequently. And many more (42 percent) included the step where the model is revised based on data:

"Revision of the model will take place…"

"Edit model and add new ideas to concept."

About 23 percent of the teachers included the step where student explain results based on science (F) and 21 percent of the teachers included the step where students present a consensus model. However, only 15 percent of the teachers wrote about students analyzing data (E) and only 9 percent included the step where students develop hypotheses to test experiments (B).

When combinations of steps in the inquiry process were analyzed, we found 27 different combinations. Almost half the teachers (45 percent) included at least steps A and D: they had

students generate naïve models (A) and conduct observations or experiments (D), with some including one or another step as well.

Comparing the Notions of Scientific Inquiry: Before and After the Summer Institutes

When we compared the answers that look at the source of inquiry question and the process of scientific inquiry in the first and second survey, we found that more teachers had students generating the inquiry question on the first survey and more had the teachers generating the question on the second survey. In addition, more teachers did not specify who generates the question on the second survey. It seems likely that this was because by the time of the second survey was given, teachers were more focused on the issue of generating models than on generating questions (see Figure 9).

Source of Inquiry Question	Survey #1	Survey #2
Teacher generates question (guided inquiry)	6%	17%
Student generates question (independent inquiry)	33%	15%
Both guided and independent inquiry	4%	6%
Unspecified who generates question	24%	34%
Implies a question	8%	4%
No question	24%	23%

Figure 9. Sources of inquiry questions (before and after the two-week workshops)

In addition, teachers' descriptions of the process of inquiry were much more comprehensive on the second survey compared to the first. There was a notable increase in step (A), where students generate naïve models (from 14 percent to 53 percent); step (C), where students conduct a series of observations or experiments (from 53 percent to 83 percent); step (D), where students analyze data (from 4 percent to 15 percent); step (E), where students explain results based on science (from 4 percent to 23 percent); step (F), where students revise models (from 0 percent to 40 percent); and step (G), where students present a consensus model (from 0 percent to 21 percent). At the same time, the number of responses that did not mention any of the steps in the inquiry process decreased (from 31 percent to 6 percent). On the other hand, there was a decrease in step (B), where students develop hypotheses to test experiments (from 33 percent to 9 percent).

Comparing the Notions of Scientific Inquiry between PISA and Comparison Teachers after One Year

This section will report on the inquiry survey administered to PISA and comparison teachers at the end of the 2008-2009 school year. As we mentioned above, PISA teachers took the survey three times (before and after the summer workshops and at the end of the school year), while the comparison teachers only took the survey at the end of the year. A total of 38 PISA teachers and 26 comparison teachers responded to the first question of survey. One of the PISA teachers skipped the first question entirely and the other said it was not applicable, while seven of the comparison teachers skipped the question and one said it was not applicable. A total of 39 PISA teachers and 27 comparison teachers answered the second question. One of the PISA teachers and three of the comparison teachers skipped the question, while four of the comparison teachers said it was not applicable.

In the first question, we asked the teachers to describe what a science class is like when students are doing inquiry. When we compare PISA and comparison teachers at the end of the year, we see that while over half of the PISA teachers (55 percent) did not specify the format of the class, many more of the comparison teachers (81 percent) did not do so. Most of the remaining PISA teachers (45 percent) described the class as working in groups, but only about one-fifth (19 percent) of the comparison teachers included this. In other words, the percentage of the PISA teachers who mentioned group work was more than twice the percentage of comparison teachers who did so (see Figure 10).

	PISA Teachers		Comparison Teachers	
Coding Scheme	**Count**	**Percent (n=38)**	**Count**	**Percent (n=26)**
Group work	17	45%	5	19%
Individual work	0	0%	0	0%
Group and individual work	0	0%	0	0%
Unspecified	21	55%	21	81%
Students will interact with each other	8	21%	11	42%

Figure 10. Comparison of PISA vs. Comparison Teachers' Post- Survey Responses

However, 42 percent of the comparison teachers described the students interacting with one another, twice the percentage of the PISA teachers who included this (21 percent). This seems to be because the description of group work assumed interaction. Thus, when we look at the changes for the PISA group alone from pre- to post-survey, we see a shift from describing interaction generally to describing group work specifically. Note that this comparison matches the PISA group's pre- and post-survey responses, reducing the total number of pre-surveys to 38 (see Figure 11 below). Note that no teacher described individual work or a combination.

	Pre-Survey		Post-Survey	
Coding Scheme	**Count**	**Percent (n=38)**	**Count**	**Percent (n=26)**
Group work	10	26%	17	45%
Individual work	0	0%	0	0%
Group and individual work	0	0%	0	0%
Unspecified	28	74%	21	55%
Students will interact with each other	22	45%	8	21%

Figure 11. Comparison of PISA Teachers' Pre- and Post-Survey Responses

We then asked the teachers to identify the source of the inquiry question or who generates the question. Our analysis of teachers' responses revealed six categories as sources of the inquiry questions- teacher generates question (guided inquiry), students generate question (independent inquiry), both guided and independent inquiry, unspecified who generates questions, implies a question, and no question. Sample responses are written below.

"I [teacher] ask them how water cycle occurs and the example." (Guided Inquiry)

"Students are asking questions" and "I encourage them to ask questions." (Independent Inquiry

"Students…find answers to questions they have or have been presented to

them." (Both Guided and Independent Inquiry)

"When the students are doing inquiry, they are…trying to find a solution to a question or problem." (Unspecified)

"The students...find out why certain things are." (Implied)

Although more comparison teachers (38 percent) than the PISA teachers (29 percent) described students as generating questions for the inquiry, many more comparison teachers (54 percent) than PISA teachers (37 percent) failed to specify any inquiry question at all. The counts and percentages were as follows:

Coding Scheme	PISA Teachers		Comparison Teachers	
	Count	Percent (n=49)	Count	Percent (n=26)
Teacher generates question (guided inquiry)	2	5%	0	0%
Students generate question (independent inquiry)	11	29%	10	38%
Both guided and independent inquiry	1	3%	0	0%
Unspecified who generates question	7	18%	1	4%
Implies a question	3	8%	1	4%
No question	14	37%	14	54%

Figure 12. Sources of inquiry questions (post-survey)

The next question dealt with the process of scientific inquiry. When we compared the post-survey results for the PISA and comparison teachers, the major difference was that half of the comparison teachers did not mention any steps, while 32 percent of the PISA teachers failed to do so. In addition, more PISA teachers referred to generating naïve models (A), developing hypotheses (B), and explaining results based on science (E)—all aspects of inquiry that were emphasized in the summer workshops—and the PISA teachers also included more steps in combination:

Coding Scheme	PISA Teachers		Comparison Teachers	
	Count	Percent (n=49)	Count	Percent (n=26)
Teacher generates question (guided inquiry)	2	5%	0	0%
Students generate question (independent inquiry)	11	29%	10	38%
Both guided and independent inquiry	1	3%	0	0%
Unspecified who generates question	7	18%	1	4%
Implies a question	3	8%	1	4%
No question	14	37%	14	54%

Figure 13. Comparison of PISA vs. Comparison Teachers' Post-Survey Responses (Sources of Inquiry Questions)

The next question dealt with the process of scientific inquiry. When we look at the steps in the inquiry process, we see very few differences between the PISA and comparison teachers. More comparison teachers described students developing hypotheses to test experiments (B) than PISA teachers (26 percent compared to 10 percent) but fewer comparison teachers wrote that students

would generate naïve models (A) (4 percent compared to 10 percent), but the number was still small.

Coding Scheme	PISA Teachers		Comparison Teachers	
	Count	Percent (n=39)	Count	Percent (n=27)
Students generate naïve models (A)	4	10%	1	4%
Students develop hypotheses to test experiments (B)	4	10%	7	26%
Students plan investigation ©	8	21%	6	22%
Students conduct a series of observations or experiments, using different techniques or approaches (D)	26	67%	17	63%
Students analyze the data (E)	2	5%	1	4%
Students explain results based on science (F)	11	28%	7	26%
Students revise models (G)	2	5%	0	0%
Students present consensus model (H)	0	0%	0	0%
Students Conduct additional experiments (I)	3	8%	3	11%
Students further revise the model (J)	0	0%	0	0%
Students present final model (K)	0	0%	0	0%
None	10	26%	6	22%

Figure 14. Comparison of PISA vs. Comparison Teachers' Post-Survey Responses (Processes of Scientific Inquiry)

In general, the PISA teachers' description of the inquiry process was not nearly as complete or elaborated on the post-survey compared to the pre-survey. In particular, far fewer teachers included students generating naïve models (A) (from 56 percent on the pre-survey to 10 percent on the post-survey), conducting observations or experiments (D) (85 percent to 67 percent), analyzing data (E) (15 percent to 5 percent), revising their models based on data (G) (46 percent to 5 percent), and presenting consensus model (H) (21 percent to 0 percent). There was only one increase in the post-survey, with a higher percentage of teachers describing students planning investigations (C) (8 percent to 21 percent):

Coding Scheme	Pre-Survey		Post-Survey	
	Count	Percent (n=39)	Count	Percent (n=39)
Students generate naïve models (A)	22	56%	4	10%
Students develop hypotheses to test experiments (B)	3	8%	4	10%
Students plan investigation ©	3	8%	8	21%
Students conduct a series of observations or experiments, using different techniques or approaches (D)	33	85%	26	67%
Students analyze the data (E)	6	15%	2	5%
Students explain results based on science (F)	10	26%	11	28%
Students revise models (G)	18	46%	2	5%
Students present consensus model (H)	8	21%	0	0%

Students Conduct additional experiments (I)	4	10%	3	8%
Students further revise the model (J)	3	8%	0	0%
Students present final model (K)	1	3%	0	0%
None	2	5%	10	26%

Figure 15. Comparison of PISA Teachers' Pre- and Post-Survey Responses (Processes of Scientific Inquiry)

Lessons Learned and Next Steps

Technological literacy as well as scientific literacy are crucial 21st century learning goals for students. The purpose of this study was to examine the PD program in terms of its contributions to teachers' content knowledge in science and engineering, and teachers' notions of scientific inquiry. The PISA program was designed to help teachers implement science and engineering lessons in elementary classrooms in response to the challenges presented by the Committee on K-12 Engineering Education (2009) and recommendations by the *Rising Above the Gathering Storm* report (Committee on Prospering in the Global Economy of the 21st Century, 2007). The professional development model used in the program was based on path mentioned by Kennedy (1998) to promote teacher knowledge and pedagogy. As suggested by Ingvarson, Meiers, and Beavis (2005), our PD contained multiple levels of instruction (i.e. university level, elementary, etc.), variety of methodology (i.e. lecture, hands-on, field work, etc.), and different levels of discourse (i.e. teacher, peer, and student) to connect theory into classroom practice. It also used scientific inquiry and the engineering design process to drive the instruction (Lehrer & Schauble, 2006; Lachapelle, 2007).

Based on our analysis of pre- and post-tests given to teachers, the PISA teachers' post-tests scores improved significantly compared to the comparison group, even when the PISA teachers' higher pre-test scores were taken into account. When looking at the test scores in science and engineering separately, we saw that PISA teachers' post-test scores in science questions improved significantly even when their slightly higher pre-test scores were taken into account. Similarly, looking at the engineering questions, the PISA group had a significant increase in their test scores while the comparison group had virtually no increase. In other words, teachers in the PISA group improved their content knowledge in specific earth science and engineering concepts after one year of continuous PD. These findings were similar to the reviews of Ingvarson, Meiers, and Beavis (2005) and findings of Lachapelle (2007), Campbell (2007), and Macalalag, Brockway, McKay, and McGrath (2008) that showed improvements in teachers' knowledge in science and engineering as a result of intensive PD programs.

Analysis of pre- and end of the workshop inquiry surveys revealed that the PISA teachers' notions of scientific inquiry improved after attending the summer institutes. PISA teachers were more comprehensive in their description of scientific inquiry. Specifically, there was a notable increase in their identification of scientific practices such as generating models, conducting a series of observations or experiments, analyzing data, explaining results based on science, revising models, and presenting models. However, PISA teachers' description of the inquiry process was not nearly as complete or elaborated on the post-survey compared to the pre-survey, suggesting that they struggled to accept the new concept of model-based inquiry after one year of PD. Specifically, fewer PISA teachers mentioned modeling as the process of inquiry in the post-survey and both group of teachers indicated experimentation as central to inquiry. Similar to the

studies conducted by Windschitl (2004) and Justi & Gilbert (2002), our findings suggested that PISA teachers had limited views of models and its use in the classroom, and held notions of scientific inquiry that were mostly associated with the scientific method even after a year of PD program. Moreover, Windschitl (2004) and Justi & Gilbert (2002) showed that teacher identity towards deeply engrained science teaching orientations were resistant to change.

In sum, our PD program showed several successes and challenges: (1) the program of science investigations, use of model-based inquiry, and exposure to engineering design challenges related to science content in which PISA teachers participated showed evidence of statistically significant learning increases in teachers' science content knowledge and knowledge of the engineering design process; (2) the use of engineering design challenges that are closely aligned with targeted science content appears to have an impact on increased teacher science content learning;   (3) teachers' notions of science inquiry were enhanced through workshops, and finally, (4) teachers' adoption of model-based inquiry is challenged by deeply ingrained notions of *experiment-driven scientific method* as a pedagogy for science instruction. These findings suggest several avenues for future research: investigations into teacher identity towards scientific inquiry, teachers' conceptions and implementation of model-based science inquiry, and use of engineering design and its effect on science learning and on classroom practices.

References

Biological Sciences Curriculum Study. (2006). Educating the 21st Century Workforce: Are we ready, willing, and able? *The Natural Selection*, Spring 2006.

Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain. *Educational Researcher, 33*(8), 3-15.

Carson, R. & Campbell, P.B. (2007). *Museum of Science, Engineering is Elementary: Impact on EiE on Participating Teachers.* Boston, MA: The National Center for Technological Literacy, Museum of Science.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks. *Science Education, 86,* 175-218.

Committee on K-12 Engineering Education. (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects.* Washington, DC: The National Academies.

Committee on Prospering in the Global Economy of the 21st Century. (2007). *Rising Above the Gathering Storm: Energizing and employing America for a brighter economic future.* Washington, D.C.: National Academies Press.

Crawford, Barbara .(2004). Supporting prospective teachers' conceptions of modeling in science. *International Journal of Science Education*, 26, 11, 1379–1401.

Duschl, R., Schweingruber, H., & Shouse, A. eds. (2007). *Taking Science to School: Learning and Teaching Science in grades K-8.* Washington DC: The National Academy Press.

Educational Testing Services. The Praxis Series- General Science Content Knowledge Released Items- http://ets.org/Media/Tests/PRAXIS/pdf/0431.pdf

Gess-Newsome, J. & Lederman, N.G. (1995). Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. *Journal of Research in Science Teaching, 32*(3), 301-325.

Gilbert, J. & Boulter, C. (1998). Learning science through models and modelling. In Fraser, B. & Tobin, K. (Eds.), *International Handbook of Science Education* (pp. 53-66). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Hynes, M.M. & dos Santos, A. (2007). Effective Teacher Professional Development: Middle-School Engineering Content. *International Journal of Engineering Education, 23*(1), 24-29.

Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors Affecting the Impact of Professional Development Programs on Teachers' Knowledge, Practice, Student Outcomes & Efficacy. *Education Policy Analysis Archives, 13*(10), 1-28.

Justi, R. & Gilbert, J. (2002). Science teachers' knowledge about and attitudes towards the use of models and modelling in learning science. *International Journal of Science Education*, 24(12), 1273–1292.

Kennedy, M. (1998). *Form and Substance in Inservice Teacher Education* (Research Monograph No. 13). Madison: University of Wisconsin-Madison, National Institute for Science Education.

Lachapelle, Cathy. (2007). *Engineering Our Future New Jersey: Evaluation of the Implementation of Elementary Curricula*. Boston, MA: The National Center for Technological Literacy, Museum of Science.

Lehrer, R. & Schauble, L. (2006). Cultivating Model-Based Reasoning in Science Education. In Sawyer, R. Keith (ed), *The Cambridge Handbook of the Learning Sciences* (pp. 371-387). NY, NY: Cambridge University Press.

Macalalag, A.Z., Brockway, D., McKay, M., McGrath, E. (2008). *Partnership to Improve Student Achievement in Engineering and Science Education: Lessons Learned in Year One.* American Society for Engineering Education Mid-Atlantic, Hoboken, NJ.

Macalalag, A.Z. & Duncan, R. (2010). *Changes in Teachers' Ability to Design Inquiry Lessons During a Two Year Preparation Program*. International Conference of the Learning Sciences, Chicago, IL.

Museum of Science, Boston, Massachusetts. *Engineering is Elementary.* Retrieved at http://mos.org/eie/ on February 8, 2010.

National Center for Education Statistics. Trends in International Mathematics and Science Study (TIMSS) Released Items. Retrieved at http://nces.ed.gov/timss/ on August 15, 2009.

National Center on Education and the Economy by Jossey- Bass, 2007, *Tough Choices or Tough Times,* John Wiley & sons, Sanfrancisco, CA.

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

National Science Foundation. Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) Released Items. Retrieved at http://www.cfa.harvard.edu/sed/mosart/ on August. 15, 2009

New Jersey Department of Education. (2004). New Jersey Curriculum Core Content Standards (NJ CCCS). Retrieved at http://www.state.nj.us/education/cccs/2004/ on February 12, 2010.

New Jersey Department of Education. New Jersey Assessment of Skills and Knowledge (NJ ASK) Sample Tests. Retrieved at http://www.nj.gov/education/assessment/es/ on August 15, 2009.

Sanders, L.R., Borko, H., & Lockard, J.D. (1993). Secondary Science Teachers' Knowledge Base When Teaching Science Courses in and out of Their Area of Certification. *Journal*

of Research in Science Teaching, 30(7), 723-736.

Schwarz, Christina V. (2009). Developing Preservice Elementary Teachers' Knowledge and Practices Through Model-Centered Scientific Inquiry. *Science Education, 93,* 720-744.

Schwarz, C. & Gwekwerere, Y. (2007). *Using a Guided Inquiry and Modeling   Instructional Framework (EIMA) to Support Preservice K-8 Science Teaching.   Science Education,* 91,158 – 186.

Shulman, L. 1987. Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, 54(1), 1-22.

Wiggins, G. & McTighe, J. (2005). *Understanding by Design* (expanded 2nd edition). Alexandria, VA: Association for Supervision and Curriculum Development.

Windschitl, Mark (2004). Folk Theories of ''Inquiry:'' How Preservice Teachers Reproduce the Discourse and Practices of an Atheoretical Scientific Method. *Journal of Research in Science Teaching*, 41(5), 481–512.

Windschitl, Mark (2009). Rethinking Scientific Inquiry. *NSTA Reports,* November 2009, page 3.

Windschitl, Mark (2005). The Future of Science Teacher Preparation in America: Where is the evidence to inform program design and guide responsible policy decisions? Guest Editorial. *Science Education,* 89(4), 525-534.

Windschitl, M. & Thompson, J. (2006). Transcending Simple Forms of School Science Investigation: The Impact of Preservice Instruction on Teachers' Understandings of Model-Based Inquiry. *American Educational Research Journal,* 43(4), 783-835.

Windschitl, M., Thompson, J., & Braaten, M. (2008). How Novice Teachers Appropriate Epistemic Discourses Around Model-Based Inquiry for Use in Classrooms. *Cognition and Instruction, 26*, 310-378.

Yoon, K.S., Duncan, T., Lee, S.W., Scarloss, B., & Shapley, K. (2007). *Reviewing evidence on how teacher professional development affects student achievement* (Issues & Answers Report, REL 2007- No. 033). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest.

Appendix A

Teacher Survey About Inquiry in the Classroom

To what extent do you think your science classroom could be described as an inquiry-based classroom (circle one)?

        Very much   A fair amount   Somewhat   A little bit   Not at all

In your own words, describe what a science class is like when students are doing inquiry.

_____

Please provide a brief example of student inquiry from your classroom (if possible).

Listed below are activities that students may engage in during science class. Please answer the following two-part question:

First, indicate the frequency with which you would **ideally** like your students to participate in each of these activities in your science classroom.

Second, please indicate the frequency with which you think that your students **actually** participate in each of these activities in your science classroom.

If you do not consider some of these activities appropriate for your students, circle N/A.

Please use the following scale:
- 1 = Most of the time
- 2 = A lot of the time
- 3 = A limited amount of time
- 4 = Never
- N/A = Not Applicable to my students

Science class activities	Ideal frequency	Actual frequency
Explaining why something is happening in their own way	1 2 3 4 N/A	1 2 3 4 N/A
Working with their classmates in groups	1 2 3 4 N/A	1 2 3 4 N/A
Listening to the teacher	1 2 3 4 N/A	1 2 3 4 N/A
Writing about what they learned	1 2 3 4 N/A	1 2 3 4 N/A
Brainstorming at the beginning of a unit	1 2 3 4 N/A	1 2 3 4 N/A
Conducting investigations	1 2 3 4 N/A	1 2 3 4 N/A
Reflecting on their work through writing or discussion	1 2 3 4 N/A	1 2 3 4 N/A
Explaining things in scientific ways	1 2 3 4 N/A	1 2 3 4 N/A
Asking questions about their results	1 2 3 4 N/A	1 2 3 4 N/A
Memorizing definitions of science terms	1 2 3 4 N/A	1 2 3 4 N/A
Planning investigations	1 2 3 4 N/A	1 2 3 4 N/A
Arguing from data	1 2 3 4 N/A	1 2 3 4 N/A
Reading textbooks	1 2 3 4 N/A	1 2 3 4 N/A
Using evidence to support their conclusions	1 2 3 4 N/A	1 2 3 4 N/A
Making sense of data	1 2 3 4 N/A	1 2 3 4 N/A

Working individually	1 2 3 4 N/A	1 2 3 4 N/A
Sharing ideas with others	1 2 3 4 N/A	1 2 3 4 N/A
Working on real world problems	1 2 3 4 N/A	1 2 3 4 N/A
Giving presentations	1 2 3 4 N/A	1 2 3 4 N/A

Describe the reasons, if any, that you feel are most responsible for the discrepancies between the ideal and actual amounts of time you reported above. Address any reasons in the following areas:

Student Population: _____

Resources and/or Support: _____

Policy and/or Leadership Expectations: _____

Curriculum: _____

Others: _____